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## ON THE ORIGIN OF BINARY STARS.

By T. J. J. See, B.A., B.Lt., B.Sc.

WHEN Sir William Herschel was exploring the sidereal heavens, he found a great number of stars with close companions, which he frequently measured with a view of detecting relative annual parallax. And although in this object he did not succeed, his measurements afterwards led him to a discovery of much greater importance, when he recognised for the first time that some of the double-stars are physical systems in actual revolution. The classic observations of Sir John Herschel greatly extended the list of double-stars, and more recent measurements show that some 600 of the 10,000 objects now enumerated in various catalogues are binary systems in visible orbital motion. Some of these systems are so rapid that during the last hundred years several revolutions have been accomplished, but by far the greater number are so slow that centuries must elapse before their great periods are completed. Sir William Herschel also perceived the very intimate connection between stars and nebulæ, and appealing only to the law of continuity was led to suspect that nebulæ in the course of immense ages develop into stars. Following this line of thought, he divided the whole assemblage of objects into celestial species, and a great impetus was afterwards given to his speculations by Laplace's formulation of the Nebular Hypothesis, based upon phenomena observed in the motions of the planetary system. The epoch-making discoveries following Dr. Huggins' application of the Spectroscope to the study of the heavenly bodies, have at length confirmed the conjectures of Herschel and Laplace, by showing that many of the nebulæ are masses of glowing gas in the process of condensation, and hence it now becomes a matter of great philosophic interest to investigate the process by which nebulæ have developed into stellar systems.

About four years ago the writer proposed to himself to investigate the origin of Binary Stars, and for this purpose collected a table of the orbits of various systems, from which the remarkable fact was discovered that these orbits are very elongated in comparison with the nearly circular orbits of the planets and satellites. It was at once evident that so remarkable and fundamental a difference could not be overlooked in explaining the origin of double-star systems, and the high eccentricities seemed to point with overwhelming probability to the operation of some powerful physical cause which had not left a corresponding impress upon the orbits of the planetary system. Accordingly it was immediately suspected that the cause which had elongated the binary orbits was the secular reaction arising from the tidal friction in the bodies of the stars;* and this hypothesis has been confirmed by subsequent mathematical investigation, in which methods were followed analogous to those employed by Prof. G. H. Darwin in his graphical history of the Lunar-Terrestrial system. As the results of this research seem to throw an entirely new light upon the formation of stellar systems, it may be interesting to show, in an elementary geometrical manner, how the eccentricities have been developed by the secular action of tidal friction, and to point out the probable origin of Binary Stars.

Self-luminous bodies, such as the Sun and double-stars, are certainly in a fluid state (the term *fluid* being used in the most general sense), and there is reason to believe that the viscosity or "stiffness" of the fluid is usually small. Therefore the tides raised in such masses by the attraction of foreign bodies will not be confined to the surface (as in case of the fluid oceans surrounding the nearly rigid Earth), but will extend throughout the whole mass; such tides are termed *bodily* tides, and it is with them that we are here concerned. Now, imagine a double-star system, whose components we shall call respectively Helios and Sol,† each of which is of the same order of mass, and same general physical condition as the Sun. Suppose both stars to be spheroids endowed with rotations which are rapid compared to their period of revolution about one another, in the same direction, and about axes nearly perpendicular to the plane of orbital motion.

Let the system be started with the spheroids at a considerable distance apart, so that the attraction of either upon the other becomes practically the same as if the masses were collected at the centres of gravity, and suppose the orbit given a small eccentricity. Then, since the fluid is more or less viscous, the tides raised in either mass

* The writer had previously seen no intimation that tidal friction could increase the eccentricity, but soon proved it, for the case in which the tides lag as in Fig. 1, only to discover afterwards that a similar result had been reached by Prof. George Darwin several years earlier, though it had not been given any particular prominence, and was apparently but little known.

† These names are chosen to fix the attention upon a system composed of two sun-like bodies, such as we find in double-star systems.

by the attraction of the other will lag, and if the viscosity is small the angle of the lag will be only a few degrees. For simplicity we shall now treat the spheroid Sol as having its mass collected at its centre of gravity, and examine the effects on the eccentricity arising from the tidal reaction of Helios; but it must be remembered that in general the whole effect of tidal friction in the system of stars will depend upon the aggregate effect of the double tidal reaction arising from the rotations of both bodies—a complication that renders the rigorous investigation in general very difficult.

With Sol thus reduced to a weighted point revolving in the plane of the equator and raising tides in Helios, the tidal configuration will be something like that indicated in Fig. 1.

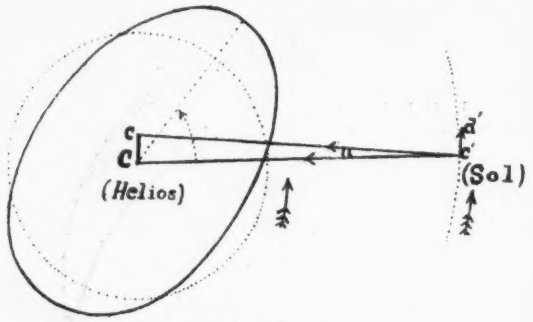


Fig. 1.

In the position of the tidal ellipsoid of Helios shown in the figure the whole attraction on Sol does not pass through the centre of inertia C (about which Helios rotates), but through some point $c$. The reaction of Sol is equal and opposite, and hence there arises a couple (with arm $c$ C) acting against the rotation of Helios. We may resolve the whole attraction of Helios ($c'$ $c$) into two components, one of which ($c'$ C) passes through the centre of inertia C and produces no effect, as it is counterbalanced by the centrifugal force of the revolving body. The other component ($c'$ $d'$) perpendicular to the radius vector is unbalanced by any opposite force, and hence acting as an accelerating force tends to increase the instantaneous linear velocity, whereby there results an increase in Sol's mean distance.

As the axial rotation of Helios is reduced, Sol is wound off on a spiral whose coils are coincident and very close together. To speak mathematically, the *moment of momentum* of the whole system is *constant*,* and since the reduction of Helios' rotation causes the axial moment of momentum to diminish, it follows that the moment of momentum of orbital motion must augment. In other words, tidal friction transfers moment of momentum of axial rotation to moment of momentum of orbital motion, and hence the mean distance must increase.

With these very brief introductory remarks, let us now examine the changes of the eccentricity of the orbit. In the mathematical works on the tidal theory it is shown that the tide-generating force varies inversely as the cube of the distance of the tide-raising body. The height of the tide, according to the principle of oscillations, varies as the square of the tide-generating force, or inversely as the sixth power of the distance. From Fig. 1 it is easy to see that (for a given lag and given height of the tide) the tangential force varies inversely as the distance.† Therefore the tangential disturbing force varies inversely as the seventh power of the distance of the tide-raising body.

When Sol is in Perihelion the tides are higher (in the inverse ratio of the sixth power of the distance) and the tangential disturbing force is greater than when Sol is in Aphelion, in the inverse ratio of the seventh power of the Perihelion and Aphelion distances. It is well known in the theories of planetary motion that a disturbing acceleration at Perihelion causes the revolving body to swing out further than it would otherwise have done, so that when it comes round to Aphelion the distance is increased. In like manner, an accelerating force at Aphelion increases the Perihelion distance, somewhat as we have roughly shown in Fig. 2. Now, if we consider the tidal frictional component to act instantaneously and only at the apses of the orbit, the effect would be to increase the Perihelion as well as the Aphelion distance, but the latter at such an abnormally rapid rate that the orbit becomes more eccentric.‡

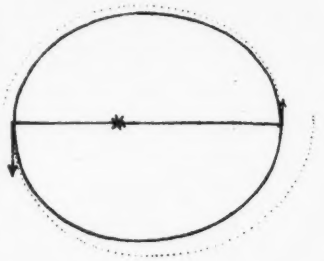

Fig. 2.

If the orbit is not very eccentric similar reasoning to that just employed for the two apses could be applied to other opposite points in the orbit, and the same general result would follow; when, however, the eccentricity is considerable, this method of procedure is not so satisfactory, though while the tides lag, as in Fig. 1, the eccentricity will continue to increase.

We shall now present the effects of tidal friction as the converse of those arising from a resisting medium, and shall determine the law of the density of the medium required to counteract the effects of tidal friction. Let us consider the case in which the orbit has only a moderate eccentricity (say not surpassing 0·3), since practically the whole disturbing force due to the tides in Helios may then be regarded as acting in the tangent to the orbit. When the tides lag (less than 90°, as in Fig. 1), the tangential component is directed forward, and hence tends to accelerate the instantaneous linear velocity; the force arising from a resisting medium is directed continually backward, and hence tends to cause the instantaneous linear velocity to diminish. The two forces are, therefore, oppositely directed, and hence it is evident that if they acted simultaneously the orbit would not undergo the least change either in size or shape, but would be rigorously stable. Now, the resistance encountered at any given point of the orbit depends upon the density of the medium, and is also proportional to the square of the instantaneous linear velocity; but from Kepler's law of equal areas in equal times, it follows that the momentary velocity of the revolving body is inversely as the radius vector. The accelerating force due to tidal friction varies inversely as the seventh power of the distance; therefore, in order to counterbalance this by a retarding force due to resistance we must suppose the density of the medium to

* The *energy* of the system, however, is not constant, but continually diminishing, owing to loss of radiant energy.

† The tangential force is always equal to the whole force acting in the line $c'$ $c$ multiplied by $\sin \iota$; $\sin \iota$, however (when $c$ C is constant), varies inversely as the radius (vector) $\rho$.

‡ If the eccentricity is to remain constant the increase must be in the ratio of $(1-e)$ to $(1+e)$; with tidal friction the ratio is more nearly $(1-e)^2$ to $(1+e)^2$, though not rigorously so, except when the eccentricity is very small.

vary inversely as the fifth* power of the distance from the centre. Such a medium would give a resistance that would just annul the changes arising from tidal friction. Now, Laplace has shown† that the action of a resisting medium increasing in density towards the centre, according to any law whatever, causes the major axis and the eccentricity of the orbit of a revolving body to diminish. Therefore, tidal friction must cause the major axis and the eccentricity of the orbit to increase.‡

The mathematical investigation to which we have referred indicates that the double-stars have arisen from double nebulæ,¶ which are certainly in general figures of equilibrium rendered stable by rotation, as is shown by comparison with figures of similar form mathematically established by Professors Poincaré and Darwin. It also appears that the orbits of the double-stars were originally nearly circular, and necessarily so, because of the very slow process by which double nebulæ separate under gravitational contraction and increasing angular velocity of rotation, whereby a division is accomplished closely resembling "fission" among the Protozoans.§ The resulting masses seem to be comparable and often nearly equal, and this result is in accordance with what we find to be the case among the double-stars. In the course of immense ages the nebulæ have condensed into stars, while secular tidal friction in the enormous nebulous masses (for a long time comparatively close together) has expanded the orbits and rendered them very eccentric. The high degree of efficiency of tidal action in the stellar systems results from the large mass-ratios of the component bodies, their state of fluidity, and their enormous absolute masses (frequently several times surpassing that of the Sun) moving at distances such as the larger planets of our own system. It is shown that if the masses were separated as we have supposed the eccentricity of the orbit would at first slightly diminish, then increase until a high maximum is attained, after which it would again diminish (when the stars have become entirely dark).

The stellar orbits are on the average more than twelve times as eccentric as those of the planets and satellites. The mean eccentricity of the 64 orbits now roughly known is 0·48, while the corresponding mean for the orbits of the eight great planets and their twenty satellites is less than 0·0389. The orbit of $\gamma$ Virginis is known with great precision, and here we have the remarkable eccentricity of 0·9; and the very trustworthy orbit of Sirius, just computed by Dr. Auwers, has the very considerable eccentricity of 0·63. From a number of other orbits whose eccentricities are very well determined the fact seems certain that the double-star orbits are generally highly eccentric, though some few appear to be more circular, in accordance with the theory of tidal evolution under what are perhaps rather abnormal conditions. Therefore we have in the general elongation of the double-star orbits a visible trace of the action of secular tidal friction, which has played so important a part in the evolution of the stellar systems mainly because of the large mass-ratios of the component bodies, and their comparative proximity during immense ages; for it must be remembered that double-stars, now condensed and widely separated, were millions of years ago much closer together and more expanded in volume, and hence the tidal action was then very much greater than at present.

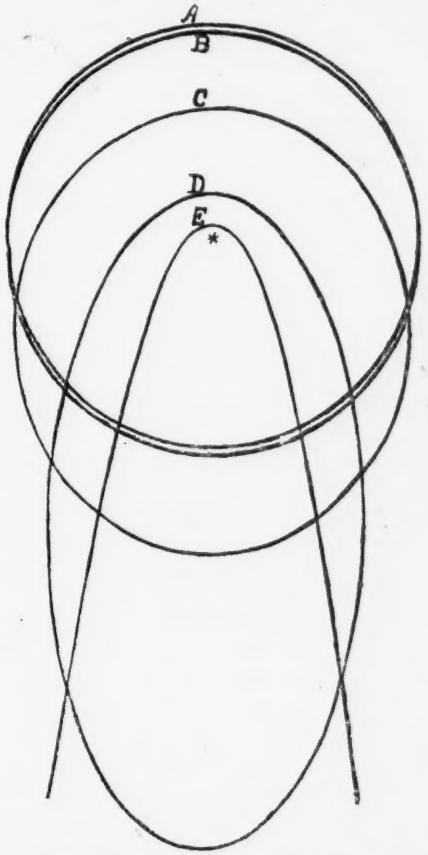


FIG. 3.—A. Circle. B Mean planetary orbit. C. Mean stellar orbit. D. Orbit of $\gamma$ Virginis. E. Parabola.

Investigation of the double nebulæ seems to indicate that double-stars were not formed as rings, but as globular masses; and since the process of separation thus disclosed would seem to be the normal form of celestial evolution, some doubt is thrown upon Laplace's theory of ring-formation as applied even in our own complex and remarkable system, composed of a great number of very small planets and satellites moving in nearly circular orbits about central bodies of a much higher order of mass. It seems hardly credible, and yet it is a fact, that our Sun has 750 times the mass of all his attendant bodies combined; the matter of the solar nebula has therefore gone nearly altogether into the Sun, while the planets and satellites are

* If $\sigma$ be the density of the medium, $\rho$ the radius vector, and $\kappa$ some constant, then the resistance R varies as $\kappa\ \sigma\ v^3$, but $v^2$ varies as $\frac{1}{\rho^3}$; therefore R varies as $\frac{\kappa\sigma}{\rho^3}$. The disturbing force F varies as $\frac{\kappa}{\rho^2}$. But R must be made equal to F, hence we must suppose $\sigma$ varies as $\frac{1}{\rho^5}$. Then $R = F = \frac{\kappa}{\rho^2}$.

† *Mécanique Céleste.* Liv. X., Ch VII, Sec. 18; or Watson's "Theoretical Astronomy," p. 552.

‡ We may add that the increase will usually continue until the rotations of both stars are nearly exhausted, after which the eccentricity will be reduced by the libratory motion of the system, and the orbit will at length become circular. The stars, however, would then perhaps be entirely dark, and hence, if in the immensity of space any such dark rigid double-star systems exist, they cannot be observed. Other relations of rotation and revolution, and various other viscosities, give rise to various other results; but the conclusion above reached is that of chief interest in connection with the great multitude of double-stars hitherto discovered.

¶ It is easy to show that double-stars have not been formed by the approach of separate stars (which would describe hyperbolas or parabolas), and hence the double-star systems must have had a nebulous origin.

§ See also the writer's papers in the *Observatory* for February and March, 1891.

entirely insignificant. On account of the very small masses of the attendant bodies, tidal friction, as Professor G. H. Darwin has shown, has not been of much importance in the solar system, and consequently the orbits of the planets and satellites have in general undergone but little change, compared to the great expansion and elongation experienced by the orbits of double-stars.

The mass of our system is nearly all in the Sun, and hence the mass-distribution is essentially single; the Binary Stars are systems of *double suns*, and the mass-distribution is therefore essentially double. If we look upon the Sun and his attendant bodies as one of the stellar systems, we cannot fail to recognise its very exceptional character. For the system is very complex, and the satellites (except the Moon) are very small compared to the planets, which are in turn equally insignificant compared to the Sun. The orbits are, moreover, in general, nearly circular, as tidal friction has been too unimportant to enlarge materially the (small) eccentricities with which they were originally endowed. By far the greater number of stellar systems appear to be composed of only two stars —two vast suns—but a few systems are made up of three and more rarely four such bodies. We could not discover, with our present optical means, planets such as Jupiter even at the short distance of $\alpha$ Centauri, and hence we cannot affirm that *such* bodies do not revolve elsewhere in the sky, especially around many of the "single" stars. It is doubtful, however, whether there are, in general, many small bodies of a planetary character in the double-star systems, for the simple reason that they could probably not long be preserved where the attraction is so complicated (by two centres of nearly equal importance, varying greatly in distance owing to the high eccentricities of the orbits). Viewed as a stellar system therefore, our system is quite unique, and its development has apparently been radically different from that prevailing among the double-stars, which would seem to be the normal form of celestial evolution.

## THE CLASSIFICATION OF THE CHEMICAL ELEMENTS.

By Vaughan Cornish, B.Sc., F.C.S.

THE researches of Stas appeared to show that the connection between the atomic weights, which Prout thought he had discovered, was either unreal or, at all events, not demonstrable. Four years after the publication of Stas's second series of researches, the Russian chemist, Mendelejeff, made known his system of classifying Elements on the basis of atomic weights—a system which has stood the test of experiment, and has pointed the way to many new paths of fruitful research in chemistry.

Chemists had been for some time familiar with the fact that among the Elements are certain "natural families," the members of which bear a general similarity to one another, and show a regular gradation of properties following the increase in atomic weight as we proceed from the lowest to the highest member. Thus Chlorine, Bromine, and Iodine have certain properties in common, known to every tyro in chemistry, which mark them as members of a group or family. Among the members of this family the properties vary in a *continuous* manner with the atomic weight. Thus Chlorine (at. wt. about $35\frac{1}{2}$) is a gas, Bromine (at. wt. about 80) is a liquid, and Iodine (at. wt. about $126\frac{1}{2}$) is a solid, and so in similar gradation with their other characters. Lithium (7), Sodium (23), and Potassium (39) are another natural family, the well-known Alkali metals. Here, again, there is a continuous gradation of properties with rise of atomic weight, Lithia, the oxide of Lithium, being a weaker base than Soda, and Potash being the strongest base of the three oxides.

The members of a natural family are termed *homologous* elements. The connection between the properties and the atomic weight among groups of homologous elements was, as we have said, known before the publication of Mendelejeff's first paper, which appeared in 1869. Mendelejeff, however, by comparing together the members of different groups or families, was led to the discovery of a new and peculiar relation between the weights of the atoms and their properties, a relation which is the basis of the present system of classification of the Elements, known as the *Periodic System*.

Writing the Elements* after Hydrogen (1) in order of atomic weight we have—

| Li. | Be. | B. | C. | N. | O. | F. | Na. | Mg. | Al. | Si. | P. | S. | Cl. | K. | Ca. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 9 | 11 | 12 | 14 | 16 | 19 | 23 | 24 | 27 | 28 | 31 | 32 | $35\frac{1}{2}$ | 39 | 40 |

and so on. There is found to be a regular gradation of properties with increase of atomic weight from Lithium to Fluorine, which are as opposite in their characters as any two elements with which we are acquainted. Increase of atomic weight from 7 to 19 has continuously diminished the electro-positive or metallic character possessed by Lithium till we reach Fluorine, a non-metal and the most strongly electro-negative element known. But after atomic weight 19 the gradation of properties does not continue; on the contrary, there is a sudden "reversion to type," the next element, Sodium (Na. 23), being strongly metallic in character. It is, as we have already mentioned, a member of the same natural family as Lithium, and in that family stands next to Lithium in order of atomic weight. As we proceed from Sodium, in order of increasing atomic weight, we find once more a gradation from the most strongly marked metallic properties to the most decided non-metallic character. Magnesium (Mg. 24) is a metal as Sodium is, but its oxide is less strongly basic than Soda. Alumina (the oxide of Aluminium, Al. 27) is weakly basic or weakly acidic according to circumstances. Silicon, a non-metallic body, forms a weakly acidic oxide, and Sulphur (S. 32) is not metallic in its physical properties, and forms an oxide which is strongly acidic or acid-forming. The next element, Chlorine (Cl. $35\frac{1}{2}$), is the first homologue of Fluorine, and is a typical non-metallic Element. The Element next following, Potassium (K. 39), is, however, a metal, and forms a strongly basic oxide. It is the third member of the group of alkali metals; so that in passing from Chlorine to Potassium we have the second instance of "reversion to type."

After Potassium, the metallic character again begins to decrease; the next Element, Calcium (Ca. 40) forming an oxide, Lime, which is a weaker base than Potash. Thus, after Potassium as after Sodium, the variation of properties goes on continuously with increase of atomic weight from one element to another for another *period*.

We will not follow these *periodic* variations further, partly on account of limitations of space, partly because the relations become more intricate and more difficult to follow as we proceed to the higher atomic weights. We

* Approximate numbers are, for convenience, given for the atomic weights. The names of the Elements symbolized above are: Lithium (Li.), Beryllium (Be.), Boron (B.), Carbon (C.), Nitrogen (N.), Oxygen (O.), Fluorine (F.), Sodium (Na.), Magnesium (Mg.), Aluminium (Al.), Silicon (Si.), Phosphorus (P.), Sulphur (S.), Chlorine (Cl.), Potassium (K.), and Calcium (Ca.).

have gone far enough, however, to show the peculiar and novel character of the relation which Mendelejeff discovered. Whereas, the properties of the Elements of any one family vary *continuously* with the atomic weight, the properties of all Elements are a *periodic* function of the atomic weight; a certain increase of atomic weight being accompanied by a recurrence of certain properties possessed by an element lower in the scale. This may be made clearer to the eye by writing the above list of 16 elements in a somewhat different way. As there is a return to the metallic character after the sixth element from Lithium, we will begin in our table a second line with Potassium on the left, thus:—

Li. 7, Be. 9, B. 11, C. 12, N. 14, O. 16, F. 19,
Na. 23, Mg. 24, Al. 27, Si. 28, P. 31, S. 32, Cl. 35½,
K. 39, Ca. 40, etc.

We see that after a *period* including seven elements, there begins a second period of seven. The difference of atomic weight between the first and eighth Element, between the second and ninth Element, and so on, is in every case, as will be seen on examining the table, sixteen units or very nearly so. Two successive members of any family are separated by six intervening elements, and differ from one another by 16 units of atomic weight. The addition of mass or weight to the chemical atom, from the mass 7 of the Lithium atom to the mass 39 of the Potassium atom, is not accompanied by a continual, unbroken increase of certain properties, but by a *periodic* variation of those properties. The interval from Lithium to Potassium comprises two periods, each of which contains seven elements. The vertical rows contain the natural families (as Lithium, Sodium, Potassium, and Beryllium, Magnesium, Calcium). Previous to Mendelejeff's work relationships could only be clearly traced between members of the same family (or homologous elements). The Periodic system of classification enables us to trace the connection between the *heterologous* elements. Among the following—

Be. 9,
Na. 23, Mg. 24, Al. 27,
Ca. 40,

Sodium (Na.), Magnesium (Mg.), and Aluminium (Al.), are termed heterologous elements, and Beryllium (Be.), Magnesium (Mg.), and Calcium (Ca.) homologous elements.

The elements Sodium, Aluminium, Beryllium, Calcium are termed the four *analogues* of Magnesium. Mendelejeff showed that the properties of any element are completely determined by that of its four analogues. Thus, supposing the properties of the element Magnesium were wholly unknown, those properties could be deduced from the properties of the analogues. Thus, the atomic weight will be the mean of those of the four analogues. Now,

$$\frac{9 + 40 + 23 + 27}{4} = 24\tfrac{3}{4}$$

which gives (approximately) the atomic weight of Magnesium. Again, take the specific gravities. They are as follows:—

| | | |
|---|---|---|
| Sodium ... ... ... | specific gravity | ·97 |
| Aluminium .. ... | ,, | 2·56 |
| Beryllium ... ... | ,, | 2·10 |
| Calcium... ... ... | ,, | 1·58 |

Mean of these values = 1·8.

Specific gravity of Magnesium = 1·75.

It will be noticed that although the difference between the weights of neighbouring elements in the horizontal rows (heterologous elements) is not absolutely constant, yet the variations are small, the interval rarely exceeding one or two units in the foregoing table, except in the case of the interval Fluorine—Sodium and Chlorine—Potassium.

At the time when Mendelejeff first drew up his table of the elements, it was found that in several cases the neighbouring heterologous elements did not fall into place, that is to say, did not come into the same vertical row with other members of the same natural family. Thus the element next to Zinc (Zn. 65), which belongs to the same family as Magnesium and comes vertically below it, was followed by Arsenic (As. 75), which thus comes vertically below Aluminium, although its properties are similar to those of Phosphorus not to those of Aluminium.

Thus we have in the second and fourth horizontal rows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Na. | Mg. | Al. | Li. | P. | S. | Cl. |
| | 23 | 24 | 27 | 28 | 31 | 32 | 35½ |
| and | Cu. | Zn. | As. | Se. | Br. | | |
| | 63 | 65 | 75 | 79 | 80 | | |

Selenium (Se.) and Bromine (Br.) have properties similar to those of Sulphur and of Chlorine respectively. These facts led to an idea entirely novel in chemistry, that of *gaps* among the elements. Hitherto, the existence of an element with any particular atomic weight and particular properties had been regarded as an isolated and, so to speak, an accidental fact in Nature, but Mendelejeff's generalization introduces the idea of the necessity for the existence of elements with such and such atomic weights, and such and such properties.

It appeared extremely probable that there existed two elements intermediate in atomic weight between Zinc and Arsenic, between which there is an interval of ten units. Supposing two such elements to exist (called provisionally Eka-Aluminium and Eka-Silicon), Mendelejeff arranged the elements in the fourth horizontal row thus:

2nd Row—Na. 23 Mg. 24 Al. 27 Si. 28 P. 31 S. 32 Cl. 35½
4th Row— Cu. 63 Zn. 65 Eka-Al. Eka-Si. As. 75 Se. 79 Br. 80

Reasoning from the assumption that the properties of an element are the mean of those of its four analogues, Mendelejeff drew up a table representing the properties of the hypothetical elements Eka-Aluminium and Eka-Silicon. Two elements having the atomic weights required by the position of Eka-Aluminium and Eka-Silicon in the table have since been discovered, and named respectively Gallium and Germanium. Their properties agree very closely with those predicted by Mendelejeff.

This power of prediction of hitherto unobserved elements was an enormous advance in chemical science. The discovery of Gallium holds in the history of chemistry a similar place to the discovery of Neptune in astronomy. The Periodic system of classification enables us not merely to say with every confidence that such and such elements exist though yet unobserved, but it puts us in a position to limit the number of possible, or at all events probable, elements. It enables us to predict with considerable accuracy the properties of chemical compounds before these compounds have been actually investigated, and it has in numberless ways proved of the greatest service to systematic chemistry. The philosophical interest of Mendelejeff's great generalization is not inferior to that of the discovery of the laws of planetary motion. The Russian chemist, like Copernicus and Kepler, has shown the existence of law or order in one of the great departments of Nature's administration. Newton showed that the laws of planetary motion discovered by Kepler were the necessary outcome of the property of universal gravitation. We yet await the discovery of a law which will account for the connection between the weights or masses of the atoms and their properties. Such a discovery would be of surpassing interest. Previous to Mendelejeff,

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all that was known of functions dependent on masses derived its origin from Galileo and Newton, and appeared to indicate that such functions always either increase or decrease with the increase of mass, as in the case of the attraction of celestial bodies. The numerical expression of the phenomena was always found to be proportional to the mass, and in no case was an increase in mass followed by a recurrence of properties such as is disclosed by the Periodic law. This is thought to indicate that the true conception of mass, and perhaps also of the mode of action of gravitation, must be sought in the study of the chemical atoms, and of the connection between them by a periodic function of their mass.

## THE SYSTEM OF ALGOL.

By Miss A. M. Clerke, *Authoress of "The System of the Stars," and "The History of Astronomy during the 19th Century," &c., &c.*

THE steady advance of exploratory research in the system of Algol promises to furnish one of the most curious and instructive episodes in the history of science. Vague hypothesis, determinate theory, and triumphant verification, have already played their logically sequent parts in the discovery of the eclipsing satellite. Goodricke's conjecture, however, had to wait nearly a century for Pickering's formulization, while this was ratified within a decade by Vogel's disclosure of the anticipated tell-tale spectroscopic effects. Progress has, indeed, of late notably quickened its pace; and we may therefore hope for a prompt and effective application of the Ithuriel-spear of adapted observation to the latest creation of speculative intelligence in the lately organized department of "dark stars."

Since Argelander's time it has been tolerably evident that Algol had other attendants besides the agent in producing its periodical eclipses. For their recurrence was shown by him to be subject to minute irregularities in point of time, and these irregularities are of such a nature as to demand for their explanation the presence of at least one disturbing mass. A highly complex piece of mechanism could plainly be seen to be at work; yet the penetration of its intricacies presented a task so formidable that astronomers of, at any rate, the present generation might well have despaired of its accomplishment. It has, nevertheless, been undertaken by Dr. Chandler; and his labours have been rewarded with an encouraging measure of success.* They have been necessarily of a more or less tentative character, and their result must be looked upon as merely provisional; but there is much reason to suppose that it at least approximates to the truth. It is, moreover, perfectly plain and straightforward; there is nothing of the *obscurum per obscurius* about it; the consequences it involves are definite, and admit of definite verification.

The new and enticing hypothesis now presented for the consideration of astronomers is mainly founded upon certain well-ascertained inequalities in Algol's period of variation. These were shown by Dr. Chandler's discussion some little time since† to be slowly compensatory. They are oscillatory, not progressive. Consistently in advance of their due time down to about the year 1804, the obscurations of the star then began to fall behind it, and the delay had accumulated in 1843 to 165 minutes. A gradual process of restoration thereupon set in, and the normal epoch was reached near the beginning of 1873. It was quickly, however, transcended, for acceleration is still going forward, and is likely to continue operative during some years to come. These irregularities are evidently comprised in a cycle considerably exceeding one hundred years; and for that very reason, it is difficult to account for them on gravitational principles; since a third body, exterior to the close pair, should, in order to produce any marked perturbational effects, revolve much nearer to them than would be consistent with so long a period. Another mode of explanation is, accordingly, resorted to by Dr. Chandler. The varying intervals needed for the transmission of light from different parts of a large orbit described by Algol and its dark satellite round a remote primary, are, in his view, the fundamental cause of the alternate anticipations and retardations in the occurrence of Algol's eclipses. They are, in fact, apparently shifted backwards and forwards in time, just in the same way as are the eclipses of Jupiter's satellites through the orbital movement of the earth.

Algol may, then, be regarded as the solitary luminous member of a multiple combination of opaque masses. The common centre of gravity, round which the pair hitherto known revolves in a period of about 131 years, lies by the present hypothesis at a distance from it just equal to that of Uranus from the sun. The path thus traced out is, we are further informed, sensibly circular, and its plane is inclined 20° to our line of vision. Obviously, however, during the whole time occupied in travelling over its remoter half, the light-minima of the star must be recorded somewhat later than if we saw them in the precise order of their actual occurrence; and this remoter half was swept over between the years 1804 and 1869, when the observed phases were always in arrear of calculation. Now, on the other hand, that the star is on the hither side of its orbit, the epochs of its eclipses are apparently anticipated, and will not coincide with their true times until the passage of the "ascending node" about 1934. The dimensions of Algol's orbit, together with its inclination, of course prescribe the amplitude of the oscillations by which its periodicity appears to be disturbed; and this "light-equation," as we may call it, proves to be 149 minutes. This should be the maximum extent, whether of acceleration or of retardation; but in point of fact, as we have seen, delay mounted up in 1843 to 165 minutes. Hence the theory cannot be said to represent the observations as satisfactorily as could be desired. The deviations, indeed, are large enough to suggest to Dr. Chandler further complications, the unravelment of which may challenge the utmost skill and patience of investigators. Meantime, a touchstone of the general truth of his hypothesis will soon be at hand; for it involves a cessation within the next ten or twelve years, and a subsequent reversal, of the shortening process at present affecting the star's period of luminous change; and the fulfilment of this prediction will serve as a hall-mark of its genuine quality. An additional test may be derived from spectrographic evidence. The velocity of Algol in the large orbit attributed to it is 2·7 miles a second; but of this, less than one half, or about one mile per second, is at present directed towards the earth. It constitutes, however, a goodly proportion of the 2·3 miles of continuous approach determined from the Potsdam plates; but which should in the course of a score of years, if the new theory be true, completely disappear, neutralized by the altered direction of the star's orbital motion. It remains, indeed, to be seen whether the whole of its supposed translatory speed may not really be of a circulatory character.

Dr. Chandler's theory does not rest wholly on the cyclical inequalities of Algol's light-changes. He alleges

* *Astronomical Journal*. Nos. 255, 256.
† *Ibid*, vol. vii., pp. 165-183.

also in its support periodical disturbances of proper motion, brought to view by a careful discussion of all the observations of the star, from 1753 to the present time, and indicating, in his opinion, a combination of elliptical travelling with a progressive advance. But the average proper motion of Algol is so very small—less than two seconds of arc a century—that variations or irregularities in it can at present be regarded only as an interesting possibility. They would give, if confirmed, 2·7″ for the longest diameter of the ellipse into which the wide orbit traced out by Algol round its unseen primary is projected upon the sky. And since this little span represents an actual expanse of 38 earth-to-sun distances, or "astronomical units," it implies a parallax for the star of 0·07″, corresponding to a distance of nearly 47 light years—a statement that is in many ways worth thinking about. Although claiming only qualified credence, it nevertheless conveys the upshot of assuredly the most promising attempt yet made to determine, by indirect means, the parallax of a star. In itself, too, it seems probable enough. Assuming its accuracy, we gain the information that Algol emits 63 times as much light as the sun, which, in its place, would show with little more than the brightness of a seventh magnitude star. The famous variable, moreover, according to Dr. Vogel, is just one million of miles in diameter, so that it presents only once and a third the solar radiating surface; yet it is, as a light-giver, 63 times more effective. The remarkable conclusion follows, that Algol is intrinsically 47 times more brilliant than the sun. The emissions from its photosphere are, per unit of area, 47 times more powerful. And should its parallax eventually—as seems not unlikely—prove to be smaller than 0·7″, this disparity will be still further enhanced.

By means, accordingly, of investigations of this nature, more fully and securely carried out, the question as to comparative stellar brilliancy may finally obtain a sufficiently satisfactory answer. It is a very important one. The process by which photospheric light is manufactured is still largely enigmatical; but the ideas commonly entertained about it are not easily compatible with the existence of considerable differences in the shining faculty of photospheric shells presumably identical in point of chemical composition. Reliable evidence of such differences has not hitherto been available. That light-power in stars bore no fixed proportion to mass was patent in numberless examples; but the density, consequently the dimensions of the emitting bodies remaining unknown, it could not be determined whether distension of substance, or innate strength of incandescence, was more concerned in producing a great sum-total of light relative to quantity of matter. The indications, however, now derived from Algol are overwhelmingly in favour of the latter alternative.

The primary member of its system, even if illuminated solely by the borrowed rays of its brilliant neighbour, may not, Dr. Chandler thinks, be out of reach of telescopic discovery. But his hopes, in this case, appear somewhat chimerical. It is not difficult to show that, under the circumstances supposed, a body of planetary constitution could not possibly be disclosed by any optical means at present available. Its position-angle relative to Algol is just now, we are told, 32°; while its distance from the same star is in the inverse ratio of its mass. This is considered by our author to be indeterminate; but it is not so, unless we reject Dr. Vogel's value for the combined mass of the close pair forming the variable. Assuming its approximate correctness, and that Algol and its immediate attendant accordingly contain two-thirds the solar quantity of matter, and admitting further that they revolve together, at a distance of nineteen astronomical units, in a period of 131 years, round their common centre of gravity with another body, it follows that the mass of that body is about equal to that of the sun, and that it circulates at twelve units of distance from the gravitational centre of the system. It should be found, this being so, if found at all, at an apparent interval of rather less than 2″ from Algol. The real gap of space separating them—the radius, that is to say, of Algol's relative orbit—would be measured by thirty-one radii of the earth's orbit; and the effectiveness for visual purposes of a still problematical body, shining by reflected light alone, can hence be estimated. If of the same density with Algol, it presents a disc of fivefold area, which, endowed with Jupiter's high reflective power, or an albedo of ·62, would possess a total lustre $\frac{1}{2,980,000}$ that of the original source of its radiance. This is equivalent to saying that it should be fainter by sixteen stellar magnitudes. Yet the suppositions introduced above are perhaps unduly favourable to conspicuousness. Evidently, however, an eighteenth magnitude star, in the close vicinity of one of the second, is far below discernment with any telescopic or photographic powers likely to be in use for a considerable time, if ever; so that visual confirmation of Dr. Chandler's theory can only be looked for if the unknown mass it has brought ideally into existence be in some degree self-luminous.

That theory, as he remarks, "has a much wider cosmological meaning than the mere explanation of the phenomena" of a single star. Most "eclipse-variables" exhibit irregularities of the same type with those of Algol, and which will doubtless prove amenable to a similar explanation. Moreover, an incalculable number of stars which, from our point of view, escape eclipse, unquestionably belong to systems organized on the same general plan. One such, indeed, is already known in α Virginis, a first-fruit of discovery in this particular branch; and Procyon, perhaps, is one of many others essentially resembling it, although inaccessible to spectrographic research, because revolving in planes nearly perpendicular to the line of sight. Thus, the intimate association of dark and bright bodies of the same order of mass would appear to be no exception in the universal order. And this scarcely allows us any longer to regard a sun-like condition as representing simply and solely a stage in the condensation of a primitively nebulous mass. Some further conditions are plainly needed to produce the brilliant and concentrated evolution of light characteristic of "suns."

Dr. Chandler concludes his valuable paper with an appeal for micrometrical measures of Algol stars, adapted to detect and determine possible systematic disturbances of their proper motions. Measures of the kind might, in his opinion, lead to highly significant results which would probably, in the case of Y Cygni, be reached with particular promptitude. For the cyclical fluctuation of this star is completed in about 600 single periods, or two and a half years, and has an amplitude of no less than four hours. Hence, the orbit described, on the light aberration theory, in that short period, must, even if its plane be coincident with the line of vision, approach that of Uranus in size, and the star's movement in it should accordingly be betrayed by vibrations exceeding many times in extent those due to its annual parallax. "If the research gave favourable results in this instance," our author continues, "it could then be extended to λ Tauri, which appears to be also a promising candidate." It is to be hoped that the suggestion will not remain unheeded. Owners of heliometers could hardly turn them to better account than by applying this simple criterion to an hypothesis which, if approved as true, opens yet one more road through the daily widening field of sidereal discovery.

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## THE GREAT EARTHQUAKE IN JAPAN OF 1891.

By the Rev. H. N. Hutchinson, B.A., F.G.S.

LAST year the Japanese empire was visited by one of those great catastrophes that every now and then cause widespread destruction to life and property. The country, as everyone knows, is a land of Earthquakes. It is calculated that at least five hundred shocks occur every twelve months. Japanese people talk of Earthquakes from day to day just as we, in England, discuss the weather, and hardly a day passes without some perceptible shaking.

Our present knowledge of Earthquake phenomena is largely due to the valuable labours of Prof. Milne in Japan. We propose, in the present paper, to give some slight account of the great Earthquake of last year as described in an interesting and beautifully illustrated book* by Professors Milne and Burton, containing twenty-nine large photographs, mostly taken by one of the authors for the Japanese University. These have been very artistically reproduced and printed by a mechanical process by Mr. K. Ogawa, so that they are as permanent as the paper they are printed on (which is itself a product of the Earthquake district, being manufactured only in Echizen). These illustrations will be found most helpful by anyone wishing to study the effects and phenomena of Earthquakes, for they give a far better idea than any amount of verbal description, and for the time being one almost seems to be transported to the district in question, and to be studying the effects on the spot.

The Nagoya-Gifu Plain, which has been so sadly devastated, is one of Japan's great gardens. It occupies the centre of the empire, and is in the prefectures of Aichi and Gifu. To give some idea of the destructiveness of this Earthquake it may be mentioned that the most severely shaken district, in many portions of which the destruction of buildings and engineering works was complete, extends over 4200 square miles. Brick buildings were affected over a still larger area, viz.: as far as Tokyo to the east, and Kobe to the west; but the disturbance made itself felt over an area of 92,000 square miles. The authors estimate that, if the Japanese islands presented a larger surface of land, the effects might have spread over an area of 400,000 square miles. They tell us that a disturbance occurred in the Mino mountains, and at once an area greater than that of the empire of Japan became a sea of waves, the movements being magnified on the surface of the soft alluvial plains. In Tokyo, more than 200 miles from the centre of the disturbance, the ground moved in long easy undulations, producing in some persons dizziness and nausea, the movements being not unlike what we might expect upon a raft rising and falling on an ocean swell. But near to this centre the waves were short and rapid; whole cities were overturned, the ground was rent, small "mud volcanoes" were created, and the strongest of engineering structures were ruined. The loss of life was fearful; about 10,000 persons were killed, 15,000 were wounded, 100,000 houses were levelled with the plain, whilst almost every building in the inner seismic region was shattered. From these effects it is concluded that the earth-movements in Mino at the time of the great Earthquake were at least equal to any movements recorded in the annals of seismology.

In speaking of the possible causes of Earthquakes, the authors point out that in the Nagoya-Gifu district there are neither volcanoes nor volcanic rocks; the plain is a bed of alluvium lying in a basin of palæozoic hills, and it was in these hills that the disturbance began. Hence it does not appear that this was one of those cases in which an Earthquake is connected with volcanic action, as many undoubtedly are. Rather it suggests a huge, internal, sudden jar, and possibly a slip or displacement, producing what is known to geologists as a "fault." In the general process of mountain formation, by which strata are compressed, contorted, and elevated above the level at which they were originally formed in lakes, seas, or estuaries, fractures must from time to time take place, when the internal strain becomes greater than they can bear. Geologists have sought the cause of such movements as these, by which mountain ranges are upheaved, in the secular cooling of the earth, whereby the outer layers cooling and contracting less rapidly than those down below, tend to be left unsupported, so that in settling down, they are thrown into folds, much in the same way as the skin of a dried apple is wrinkled. But it must be admitted that at present the subject of earth movements of all kinds —the slow movements producing elevation and depression of lands, or the sudden movements whereby the surface of the earth is shaken—is still involved in much obscurity.

Leaving these questions, let us turn our attention to the actual effects produced by the Great Earthquake in Japan last year. The greatest destruction has taken place along and near the river banks; the reason of this seems to be that, being unsupported on one side, the momentum of the shock has shot them forward much in the same way that the last of a series of railway waggons is shot forward when a locomotive bumps against the other end. Our illustration† shows the kind of destruction which has occurred along the banks of the Biwajima River for a distance of several miles. Innumerable longitudinal clefts occur, of all widths up to about two feet; also the inner half of the embankment has slid down towards the river to some extent, sometimes to a number of feet, measured vertically. At one place the embankment is entirely gone for a couple of hundred feet or so, and here a very strange thing has happened: a large bamboo grove and a few pines just at the back have been pushed sixty feet back, and yet the bamboos and trees remain upright! It will be seen that one thatched roof has fallen intact. The longitudinal cracks are well seen in the illustration.

The road from Nagoya to Gifu is a series of villages, or rather *was*, a nearly continuous street of more than twenty-five miles in length; *now*, except in a few cases, it is simply a narrow lane between two long heaps of *débris* that were once houses. The recent Earthquake teaches us that wooden houses, built on European models, have suffered less than ordinary Japanese dwellings, which have heavy roofs, no diagonal bracing, and light supports. No wonder that the heavy roof brings the whole structure down.

The disturbance seems to have been greatest in the famous Neo Valley, where the ground has been both elevated and depressed. The people say that the mountains themselves have been depressed, so that from certain points, hills, formerly invisible, can now be seen.

Earthquakes frequently cause landslips, and in this case we find that landslips were taking place for several days after. People who witnessed them were greatly impressed by the roaring noise and vibration. It is probable that the sounds are transmitted through the earth.

* "The Great Earthquake in Japan, 1891," by John Milne, F.R.S., Professor of Mining and Geology, Imperial University of Japan, and W. K. Burton, C.E., Professor of Sanitary Engineering, Imperial University of Japan. Published by Lane, Crawford & Co., Yokohama, Japan; Agent for this country, Edward Stanford, Cockspur Street, Charing Cross.

† Our Illustration is copied from the Photograph of Profs. Milne and Burton, by the kind permission of Messrs. Stanford.

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THE BANKS OF THE BIWAJIMA RIVER AFTER THE GREAT EARTHQUAKE IN JAPAN, OCTOBER 27th, 1891.

From a Photograph by Professor JOHN MILNE and Professor W. K. BURTON, of the Imperial University of Japan.

The Bamboo Grove and Houses formerly on the embankment have slipped down into the bed of the Stream, the Trees still remaining upright. In the right hand foreground are some remarkable cracks, one of which might be mistaken for the body of a military man in a sitting posture.

*Automatic Engraving Co., Strode Rd., Willesden Green.*

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There are some capital photographs illustrating the effects produced on the Nagoya Railway Bridge—a lattice girder-bridge. The broken cast iron piers lie on the dry shingly bed of the river, and the original line of the bridge has, in its central part, been deflected up stream. At one place a group of four or five houses has completely sunk into the earth; only the roofs are to be seen, and on looking under them, instead of the confused heap of rubbish found under other houses, there is merely the surface of the ground, the same level inside as outside! The unfortunate persons who were in these houses at the time, lie buried, no one knows how deep.

It might seem at first sight as if it were quite impossible to mitigate the terrible effects of these disturbances, but experience teaches that there are ways in which much destruction to life and property may be avoided. Thus, it is known that on certain sites, buildings are not so much swayed and disturbed as on others only a short distance away. Thus the nature of the ground makes a good deal of difference, and buildings on soft ground, such as is generally found on plains, suffer more than those situated on hard rocky ground. River banks and the edges of cliffs are dangerous sites, because of the forward swing of the free face. The movements at the bottom of a pit, or even in a shallow railway cutting, are less than those upon the natural surface; hence buildings rising from a pit, or with an area or basement, are less severely shaken. In building in a country much visited by Earthquakes, it is very important to construct with a view to resisting movements of a more or less horizontal nature—not merely up and down movements. Consequently, a heavy roof is a thing to be avoided, because by its own inertia it may break the support beneath, and come crashing down. In Italy arches are forbidden in Earthquake regions, for arches fall apart readily when acted upon by horizontal movements. A series of rules have been formulated for Japan, and it is much to be hoped that these rules will receive from builders the attention they deserve. The Nagoya-Gifu Plain is a region where Earthquakes are frequent. Violent disturbances took place in the northern part of Gifu in 1826, 1827, and 1859. But there is no doubt that in this district seismic activity is gradually becoming less; the occurrence of great disasters has been separated by longer and longer intervals. Many interesting problems in seismology have yet to be solved, but Prof. Milne's labours in Japan will at least form a valuable foundation for future workers in this field of research to build upon.

## THE GREAT SUNSPOT AND ITS INFLUENCE.

By E. W. MAUNDER, F.R.A.S.,

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IT would be a very difficult and toilsome task to obtain a satisfactory record of the perturbations of the magnetic needle, were it not for the assistance which photography has given us. But it is no longer necessary to have relays of observers reading the instruments at intervals of two minutes through every hour of the twenty-four; by a very simple and effective arrangement the needles record their own positions, not merely at two minute intervals, but continuously. A light mirror is attached to the needle, and a gas lamp or other source of light is so arranged that a beam of light proceeding from it and falling on the mirror is reflected off to fall on a drum covered with sensitive paper. The drum is turned by clockwork and revolves once in the twenty-four hours. If then the magnet remains absolutely still, the spot of light falling on the paper will leave a blackened trace upon it which, under such circumstances, will form a straight line right round the drum. But if from any cause the magnet should twitch or turn to one side or the other, then the spot of light will be thrown up or down on the drum, and a zigzag will be introduced into the trace. As the light is shut off from the gas-jet by the clock at each hour there is then a slight interruption in the trace, and should a deflection be indicated it is only necessary to see between which hour-marks it lies, and to measure its distance between them to ascertain the exact minute at which the disturbance took place. In order that the hour-marks may be correctly identified, the light is cut off by hand at some specified time. In the copy of the trace for the twenty-four hours extending from noon of February 12th to noon of February 13th, given in the adjoining plate, will be seen that this break occurs at about a quarter to nine in the evening of February 12th.

One result of this automatic method of registration is that it becomes possible to ascertain whether or no a disturbance is truly simultaneous for the magnets at widely separated stations. This is a matter of first importance, for if it be clear that the magnets the world over are all disturbed at practically the same instant, we are precluded from finding the cause in anything restricted or local, and it becomes possible to accept an explanation which connects the disturbance with solar changes.

The accompanying plates are simple photographic copies, unmanipulated and unaltered, of the original automatic registers of two of the magnets at the Royal Observatory, Greenwich, for the period from noon on February 12th to noon on February 14th. The two magnets in question are those which record the "declination" and the "horizontal force" respectively—the declination, that is to say, the divergence of the needle from the true geographical north; the "horizontal force" is a measure of the intensity of the magnetic action, but the total amount of that intensity is not observed directly; it is observed in two directions at right angles to each other, the one horizontal, the other vertical, the record of the former only being given here.

From noon on February 12th, for seventeen hours, the trace shows that the magnets were almost quiescent. The bending down of the declination trace during the early afternoon of February 12th, its upward turn towards evening and through the night, until past midnight, are typical of the regular diurnal movement. At times of great stillness this gentle wave motion goes on day after day, unbroken even by the little breaks and ripples which the trace shows in this particular instance.

And now, before looking at the sudden and sharp disturbance which occurred at about half-past five in the morning of February 13th, let us briefly glance at the reasons already before us, for assigning the sun a dominant influence on terrestrial magnetism. First of all, there is this daily swing, westward in the morning and early afternoon, eastward in the evening and night, a swing which goes on perpetually day after day, which shows so clearly by its conformity to the length of the solar day, and by its being an action, not simultaneous over all the earth, but varying with the local time, that it is connected with the position of the sun relative to the place where the observations are being made. Next, there is a yearly, or rather, a seasonal variation, the amount of this daily change and the intensity of the magnetic force being least in the winter—the local winter—rising to a maximum a little before and again a little after midsummer. Here, again, is a second distinct, indisputable local effect, connected with the manner in which the given locality is presented towards the sun. The daily rotation of the

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earth on its axis, the yearly revolution round the sun, are both distinctly recognised by the magnets, and, if necessary, we could determine the exact period of either by magnetic observations alone, if carried on for a sufficient length of time.

But the third relation is of a different order altogether. It is that to which I referred in the first part of this paper when I said that "when we take average results for successive years we find that this motion," *i.e.*, the diurnal range, "is greater in amplitude and force in strict proportion to the number and size of the spots upon the sun."

It is now more than forty years since the occurrence of a regular periodicity in the numbers and dimensions of Sunspots was established by the observations of Schwabe, a periodicity which, though now so familiar to us as a fact, still remains as much as ever a mystery as to its cause. Just before Schwabe published his great discovery Lamont had detected a similar periodicity in the oscillations of the magnetic needle, and directly Schwabe's Sunspot results were published General Sabine and several other observers of magnetic phenomena at once recognised that the two periods were not only similar but identical.

This identity did not consist in a mere equality of the average period, or in an occasional correspondence of minima and maxima. It was far more precise. The attempt was early made to explain the Sunspot cycle as due to the influence of Jupiter, the period of revolution of that planet nearly corresponding to the mean solar cycle. But the period of Jupiter is a constant, whilst the solar cycle is irregular in length, often varying considerably from its mean value. And the collation of earlier Sunspot records soon showed that, though a fair correspondence might be made out between the planet's position and the numbers of spots seen during two or three periods, yet if we went a little further back the two got hopelessly out of step. There was, therefore, no connection there.

But the correspondence with the magnetic cycle was precise. Was the interval between one minimum and the next shorter than usual with the Sunspots? Then it was so also for the magnetic diurnal range. Was the spot maximum delayed? So was the magnetic. The two cycles have never failed to correspond in their general features since both were first under regular observation.

So far is this the case that Dr. R. Wolf, one of the first of Sunspot observers, has worked out a very simple formula by which he is able to convert the yearly means of what he terms his "relative numbers" for Sunspots, so as to represent the yearly means for the diurnal range of magnetic declination as observed at Milan, and a similar formula would serve for other localities.

The two cycles correspond also in more than their general features or annual means.

The life of a Sunspot being almost always short, and spot groups varying very much as to size and being very irregularly distributed over the sun, it follows necessarily that even at a time of maximum there are very great fluctuations in the proportion of the sun's visible hemisphere which is given up to spots. So that the rise to maximum, or the fall to minimum, does not proceed smoothly, but in a succession of waves as it were. Of these minor oscillations, any one which has been fairly well marked and at all sustained is sure to have its counterpart in the activity of the magnets.

It would almost seem a necessary corollary of this last circumstance, that particular and individual Sunspots should be attended by corresponding magnetic disturbances. It certainly was the case with the great February spot, as we have but to glance at the accompanying plate to see. At about half-past five in the morning of February 13th, the trace both of the declination and of the horizontal force magnet suffered a sharp and sudden deflection, token of an instantaneous disturbance. This sharp and sudden twitch, which occurred, so far as we know, to the needles in all the magnetic observatories of the world and at practically the same actual (not local) time everywhere, is pre-eminently typical of the intense magnetic storms. An inspection of the trace shows that its later wanderings were far more considerable than this first one, but it is its instantaneousness which gives it its special character. In the afternoon of February 13th, the magnets were vibrating to such an extent that the two traces have become intermixed. Later, about midnight on February 13th, the magnets twitched so violently that for about an hour the trace went quite off the prepared paper. The motion in declination that was registered amounted to more than 1°. The horizontal force trace went off the sheet for an hour and a half, and in vertical force (not included in the plate) the disturbance was so great that the trace was lost in one direction, that of increasing force, for four and a half hours, and in the other for an hour and a half. A period of short, quick oscillations was then set up and continued for some hours, the disturbance dying away in the course of the evening of February 14th—a little later, that is to say, than the trace is shown on the plate.

So remarkable a magnetic storm, occurring just about the time when so great a spot was about attaining its fullest development, might well be taken as proving a special connection between the two, especially when the facts already alluded to with regard to the general correspondence between Sunspots and terrestrial magnetism are borne in mind. And the conclusion would be further supported by the occurrence of a fine aurora on that same night, February 13th, for the variation in number of auroræ has also been shown to take place precisely in the same cycle as the variation in number of Sunspots.

But the proverb tells us "One swallow does not make a summer," and neither can we take one coincidence as proving a real connection. Since the spot group of February, 1892, was the largest ever observed at Greenwich, let us look through the records for the group second in size, and see if that has any information to give us.

This second spot we find in that of November, 1882. This group was seen during three successive rotations of the sun. It formed in the visible hemisphere on October 20th, increasing in size on the succeeding days with marvellous rapidity. It passed out of sight at the west limb on October 28th, and was next seen at the east limb on November 12th. Its area on November 13th, when the whole of it was visible, amounted to 1690 millions of square miles, and this area increased day after day until November 18th, when it reached the central meridian and attained its greatest dimensions, having an area of 2860 millions of square miles. After this it began to break up and to diminish again. On November 23rd its area was 2030 millions of square miles. On November 25th it had reached the west limb. It was seen at the east limb again on December 10th, its area reduced now to 515 millions, and by December 21st it had completely faded out.

What was the record of the magnets at the time when this spot was at its greatest development? This is what the Astronomer-Royal chronicles: "A remarkable magnetic storm, preceded by several days of considerable magnetic disturbance, was observed here on November 17th. It commenced suddenly November 16th, 22h. 15m. G. M. T. with a great decrease in all the magnetic elements, the declination being diminished by more than 1°, the horizontal force by more than 1-100th part, and the

vertical force by nearly 1-100th part. From 4h. to 7h., and also from 11h. to 17h., the motions were large and violent, the range exceeding 2° for the declination, and 1-50th part for the horizontal and vertical force. Earth-current disturbances were also recorded, corresponding both in time and magnitude with the magnetic changes."

Mr. Whipple, Superintendent of the Kew Magnetic Observatory, supplements this information by some additional notes not less interesting. "The disturbance," he says, "commenced about 8.30 P.M. on the night of Saturday, the 11th inst." (That is to say at the precise time, so far as it is possible to fix it, when the great spot began to come into view at the east limb of the sun.) "Throughout the whole of Sunday, Monday, and Tuesday, the magnet continued slowly oscillating through arcs of about 20′ on either side of its normal position. On Wednesday and Thursday the vibrations were frequent, but very small, partaking rather of the nature of tremors.* About 10.30 A.M. on Friday † the storm became violent, and from that hour up to 5.30 A.M. of Saturday the oscillations of the magnet and the changes of force were incessant, and frequently enormous, the declination-needle ranging at times through almost 2°."

It is unnecessary to multiply quotations, but a similar record could have been gathered from any number of magnetic observatories, a record showing a restlessness of the magnets beginning just as the spot first came into view at the west limb, and rising to the intensest excitement just about the time that it came to the central meridian and reached its greatest development.

And not merely from observatories where the study of delicate magnetic phenomena is made a speciality were such occurrences reported. "All along the railway," writes an observer in Scotland, "the block instrument bells in the railway cabins were occasionally rung as if by the operator, and telegraphic communication was much interrupted, and in some cases even temporarily stopped." Another, in the south of England, reports: "At the local post office here all the longer lines were much affected during Friday and Saturday, sometimes to an extent interfering with ordinary messages." Nor was this effect only felt in the British Isles; the American and Continental newspapers recorded just as striking interferences with the usual action of the telegraphs.

Yet a further point. Just as the magnetic storm of last February was accompanied by a fine aurora, so was that of November, 1882. Indeed the 1882 record is the more remarkable. "Auroræ of varying brilliancy," Mr. J. Edmund Clark records, "were seen at York on the 12th, 13th, 14th, 15th, 17th and 18th (morning of 19th), November the 16th and evening of 18th being too cloudy for observation; the 17th giving an exhibition of exceptional brilliancy."

Records of the aurora of November 17th are plentiful enough, and no wonder, for it was the most remarkable exhibition of the kind seen for a generation, and an entire number of KNOWLEDGE might easily be filled with different reports of it. It will be amply sufficient, however, for my present purpose to quote the very brief account which the Astronomer-Royal gave of it:—"In the evening, as soon as it was dark, a brilliant aurora was seen, commencing with a bright glow of red light extending from the north and west beyond the zenith, interspersed with pale green phosphorescent light and streamers. At 6h. 4m. a very brilliant streak of greenish light, about 20° long, appeared in the east north-east, and rising slowly, passed nearly along a parallel of declination a little above the moon, disappearing at 6h. 5m. 59s. in the west, about two minutes after it was first seen. The whole aurora had faded away by about 7h., but it burst out again at 11h. 45m., when an auroral arch, with brilliant streamers reaching nearly to the zenith, was seen from north north-east to north-west. It faded away about 12h. 10m.

The "spindle-shaped beam," as the late Mr. Rand Capron called the remarkable appearance seen just after six o'clock, was of itself sufficient to distinguish the auroral display of November 17th, 1882, from ordinary auroræ, but though it naturally attracted the greatest attention, the other and more familiar details of the phenomenon rendered it the finest seen for many years. Thus Mr. J. G. Elger speaks of it as "certainly finer than that seen on October 25th, 1870."

This second instance of the simultaneous appearance of a great Sunspot, great magnetic disturbance, and fine aurora, very materially strengthens the argument for a true connection between the three orders of phenomena. Let us push the enquiry a step further.

The third and fourth spots as to area during the period covered by the Greenwich record were upon the sun at the same time. Group No. 726 of the Greenwich series was first seen on the extreme east limb on April 10th, when it was only of small size. It began on April 16th, however, to develop very fast, and the group which had an area of 258 millions of square miles on April 15th, on April 18th covered 1620 millions, and a second great outbreak had added more than 1000 millions more by April 21st. The group reached the west limb upon April 23rd.

Group No. 729 followed No. 726 at an interval of about 30° of solar longitude, and was about 10° further south in solar latitude. It was already a giant spot when first seen at the east limb on April 13th, its area being 1340 millions of square miles. It increased steadily up to April 16th when it covered 2430 millions of square miles, and after suffering a slight decrease it reached a second maximum of 2490 millions on April 21st.

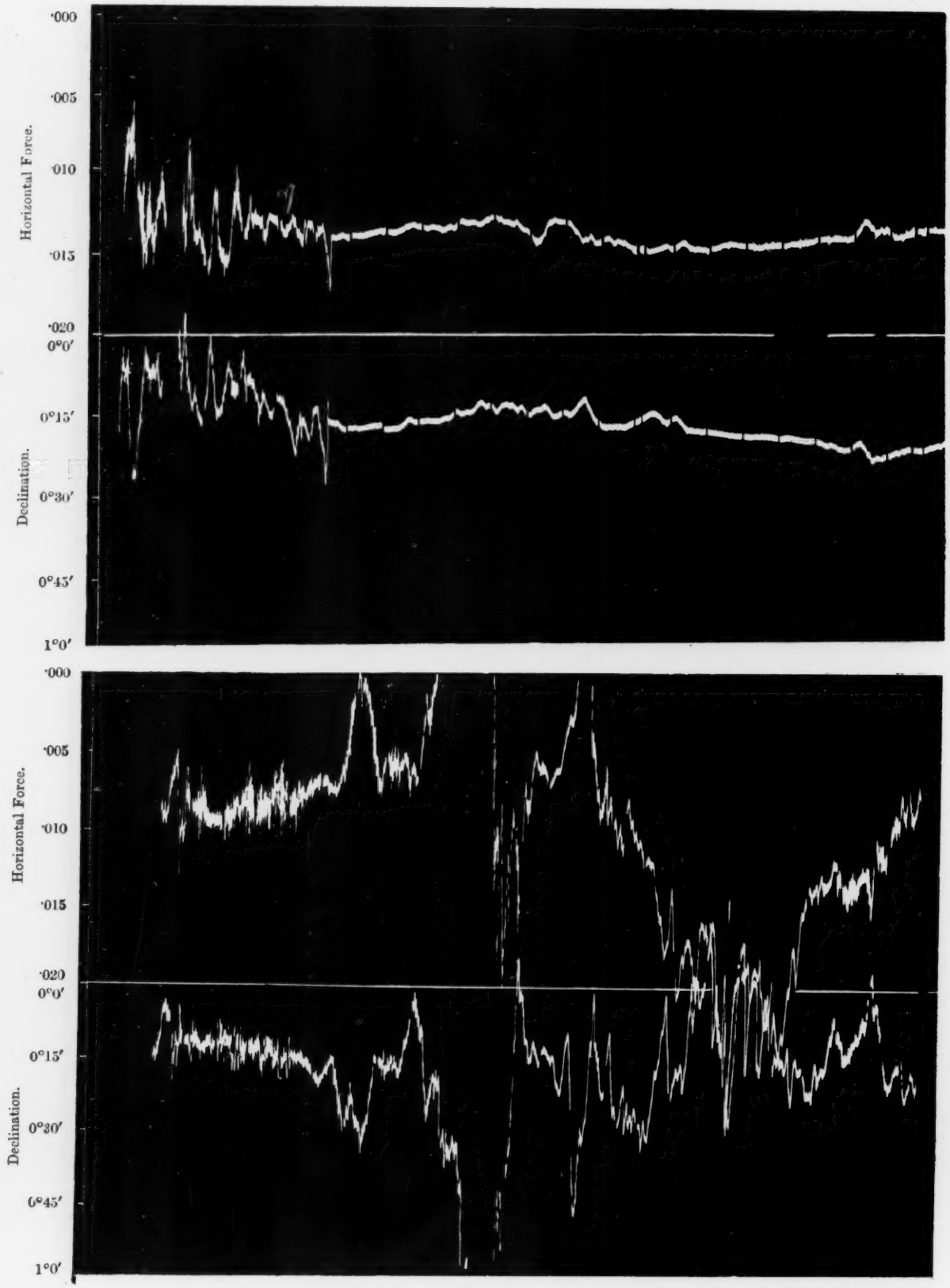
Had the magnets any record of disturbance to show? Yes, and a double one; the first on April 16th, when Group No. 726 was beginning its wonderful development and Group No. 729 had reached its first maximum; the second on April 20th, lasting till April 21st, simultaneous with the second development of Group No. 726, and the second maximum of Group No. 729. It is scarcely necessary to quote at length the official descriptions of this storm. I extract two sentences only from the account which the Astronomer-Royal gave: "The total spotted area was about double that of the greatest spotted area shown on any of the Greenwich photographs previous to this outburst"; and "since the great disturbances of 1872, February 4th, and those of October 4th of the same year" (both, I should remark, before July, 1873, when the Greenwich Sunspot record began), "no magnetic storm has been recorded equal to this."

In a period of nearly nineteen years, therefore, we have three magnetic storms which stand out pre-eminently above all others during that interval. In that same period we have three great Sunspot displays — counting the two groups of April, 1882, together—which stand out with equal distinctness far above all other similar displays. And we find that the three magnetic storms were simultaneous with the greatest development of the spots. Is there any escape from the conclusion that the two have a real and

* The Editor's expression, on page 70, "There is no brewing of a magnetic storm, it breaks out with full violence from its commencement," was not appropriate to the storm of November, 1882. It was "brewing" a good while before it burst. Similar minor disturbances were continued till the spot disappeared at the west limb.

[This seems to have been a series of magnetic storms, rather than one storm.—A. C. RANYARD.]

† Or in astronomical time, November 16th, 22h. 30m.




Traces of the Magnetic Storm of February 12th to 14th, 1892.

binding connection? it may be direct, it may be indirect and secondary only, but it must be real and effective.

Consider that the period in question is practically some 6800 days. A magnetic storm does not last many hours; a Sunspot soon declines from its greatest development, or soon passes away from the centre of the apparent disc. Suppose we take an outside limit, and give a period of two days to a giant spot to exercise its influence, or a magnetic storm to expend its violence; what are the probabilities against 3 out of 3400 of such periods of the one phenomenon agreeing with 3 out of 3400 of the other, if they are not related? If 3400 numbers were placed in one box, and 3400 more in a second, and one from each box were drawn at a time, what is the chance that the three highest numbers would be drawn from the one box, simultaneously with the three highest from the other, each to each, if the matter had not been pre-arranged? Indeed, we might legitimately call the coincidence of April, 1882, a double one, and ask the odds against the four highest numbers from each box being so drawn.

Between Sunspots and storms of the second magnitude it is more difficult to make a satisfactory comparison, because it is not so easy to frame a satisfactory definition as to what constitutes a secondary disturbance. Nevertheless, the following brief table of large Sunspots seen since the beginning of 1881 which were coincident with considerable disturbances may prove of interest. The spotted area is given in millions of square miles.

| Date. | | Spotted Area. Entire Sun. | Largest Group. |
|---|---|---|---|
| 1881. | Jan. 31 | 1295 | 686 |
| | Sept. 12 | 2089 | 917 |
| 1882. | Oct. 2 | 2480 | 1234 |
| | ,, 5 | 2065 | 1198 |
| 1883. | April 3 | 1545 | 607 |
| | ,, 19 | 2170 | 670 |
| | June 30 | 3650 | 2210 |
| | July 11 | 1887 | 1009 |
| | ,, 29 | 1425 | 1264 |
| | Sept. 17* | 2017 | 1263 |
| | Oct. 16 | 4730 | 1733 |
| | ,, 20 | 1650 | 1369 |
| | Nov. 1 | 2100 | 784 |
| | ,, 19 | 3682 | 1600 |
| 1884. | March 2 | 1510 | 609 |
| | April 24 | 2348 | 1510 |
| | ,, 30 | 1746 | 897 |
| 1885. | Jan. 23 | 1687 | 592 |
| | Feb. 5 | 1345 | 571 |
| | ,, 13 | 1569 | 480 |
| | May 26* | 1923 | 647 |
| | June 24* | 2348 | 1681 |
| | July 18 | 1835 | 504 |
| 1891. | Nov. 22* | 1966 | 1371 |

Some of the above, those marked with an asterisk, may fairly be taken as confirming, though with less definiteness, the conclusion drawn from the correspondences between the greatest spots and the greatest storms. But with the others it is not so. Spots as important have been seen upon the sun, and the magnets have scarcely fluttered, and storms as distinct have occurred when there have been only few spots, and those but small, upon the visible disc of the sun. The table is important therefore, not as adding to the weight of the evidence in favour of the connection between Sunspots and magnetic disturbances, but as emphasizing a point which must not be forgotten. Though the diurnal and annual changes of terrestrial magnetism conclusively prove the solar influence upon it, though the connection between the general Sunspot cycle and the general magnetic cycle is clearly established, though even in minor irregularities the two curves closely correspond, and though unusually large Sunspots are answered by unusually violent magnetic storms, we cannot, as yet, proceed further and express the magnitude or character of the magnetic disturbances in terms of the spotted area of the sun, or of its principal groups at the time of observation. The conclusion to my own mind seems to be that though Sunspots are the particular solar phenomenon most easily observed, we must not therefore infer that their number and extent afford the truest indication of the changes in the solar activity which produce the perturbations we remark in our magnetic needles.

## Letter.

[The Editor does not hold himself responsible for the opinions or statements of correspondents.]

### DARK NEBULOUS MASSES.

*To the Editor of* KNOWLEDGE.

DEAR SIR,—I see that you take for granted the existence of dark nebulous masses. It appears the easiest hypothesis to account for the curious features shown in the Milky Way; and the evidence for it seems strong, but is it yet sufficient, or may there not be some other way of accounting for the dark features? The fact that the dark regions are so often closely surrounded by stars shows that there are peculiarities in the arrangement of the stars with respect to the dark areas. Is it not, therefore, possible that the dark regions may be simply spaces for some reason devoid of stars?

With reference to the tree-like dark object—(flower-like I should be more inclined to call it)—referred to on page 230 in your December number, there is one feature which is very striking to me that you show only partially, and that is a straight line extending in a slanting direction from the bottom of the stalk to the left. You draw the portion of the line to the right. The large photograph in the December number shows this feature very distinctly as three straight parallel lines of stars, of which the two outer ones are by far the plainest. The passages between them are very slender, the northern one so slender as to give one almost the impression of a scratch on the photograph. This shows the advantage of having copies from more than one negative to compare, as this feature is also visible in the photograph in your October number, only not quite so distinct. Other less distinct lines emanate from the structure, and give to my eye quite an appearance of radiation, which your drawing, Fig. 1, December number, only partly indicates. Nearly parallel with the straight line from the lower part of the flower-like structure but detached from it, there is another slender dark straight line, also visible on both your photographs. These dark lines remind one of the straight nebulous lines in Mr. Roberts' photograph of the Pleiades.

Yours faithfully,

Sunderland. T. W. BACKHOUSE.

[A close examination of the photographs shows that the density of the photographic action has been less within the dark areas referred to than over surrounding and neighbouring regions. This shows that the appearance of darkness is not an effect of contrast, and that there is either less nebulosity within the regions surrounded by stars, or that there is some opaque or semi-opaque matter within the dark regions which cuts down the light of the background. The dark areas are of various depths of blackness, as if some were due to masses of faint luminosity, while others were due to an opaque fog in space.—A. C. RANYARD.]

XUM

## ANTS' COMPANIONS.—I.

By E. A. Butler.

IT has already been pointed out that an Ants' nest may contain more than one kind of insect, and we have shown how some Ants may be associated with others as guests, parasites, or auxiliaries. But when we have shown this, we have by no means come to the end of the matter: other insects, structurally unlike Ants, are also to be found in the nests intermixed with the true proprietors, and the alien population of this kind may, in a large community, be considerable. In the nests of the various European Ants there have been found nearly six hundred different kinds of insects other than Ants, and even this long list does not quite exhaust the catalogue of visitors; sundry species of invertebrate animals which are not insects, such as crustaceans, mites, &c., must be added to complete the total. Of the creatures hitherto registered as occurring in Ants' nests, however, by far the greater number are true insects, belonging to the order of beetles (Coleoptera). Some of these are, no doubt, accidental visitors and not true inhabitants: still, many are genuine lodgers in the nests, and some are found only in such situations. A very large proportion of the Ants'-nest beetles, again, are representatives of a single section of that great order, the division called Brachelytra, or Rove-Beetles. The scientific name of the group means "short wing covers," and refers to one of the most distinctive characteristics of the beetles (see Fig. 1); they carry their wings neatly packed away under two small squarish covers or elytra, which represent the fore wings, but which do not cover the abdomen as they do in most beetles, but lie over its extreme fore-part only, leaving all the rest exposed, giving thereby an earwig-like appearance to the larger members of the group, as was pointed out in the article on earwigs some months ago. Beetles of this kind are extremely numerous in the British Islands, where they usually act the part of scavengers, devouring carrion, dung, rotten fungi, and other animal and vegetable refuse. It is chiefly *small* species of these insects that inhabit Ants' nests, creatures scarcely larger, and sometimes much smaller, than the Ants themselves. Most people have probably noticed certain small species of Brachelytra, for an exceptionally warm and sunshiny day in early spring is sure to entice swarms of them from their hiding-places, when they will gaily disport themselves in our streets, running rapidly over the ground, or spreading their filmy wings and sailing through the air regardless of obstacles, often, therefore, proving themselves an annoyance by getting into the eyes of passers-by. The "fly in the eye" as often as not consists of these tiny insects. Such species would as a rule, however, not be the particular kinds that are found in Ants' nests, though they will serve very well to give a general idea of the form of these latter.

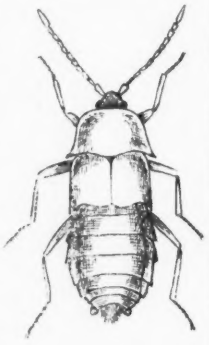


Fig. 1. — *Atemeles emarginatus*, a beetle living in Ants' nests, magnified 8 diameters.

The present season of the year is one of the best times to find these brachelytrous Ants' guests, and as the method of search for them is simple, a few words on the subject may perhaps incline some of our readers to look for them. The nests of the Wood Ant (*Formica rufa*) are some of the easiest and most profitable to commence operations upon. The mounds of these insects will now be just beginning to rise, the Ants waking to renewed vigour after their winter rest, and fortunately it will not be necessary to pull the nest to pieces, or otherwise greatly interfere with the labours of the workers in order to find the beetles; such an operation would be both disagreeable and needlessly destructive. All that has to be done is to select a few bricks or large flat stones, and place them on the nest sloping round its sides; a few broken bits of wood, such as fragments of dead branches, may usefully be added on the top of the nest, and a number of nests within easy distance of one another may be treated in a similar way. These pieces of brick, stone, and wood are intended to act as traps to induce the beetles to congregate on their under surfaces. A few days after the traps have been laid, the nests may be visited again, when it will most likely be found that the objects deposited are partially covered, by means of the labour of the Ants, with fragments similar to those that compose the rest of the mound. The traps may now be carefully but quickly lifted, one by one, and at once transferred in an inverted position to a cloth or a large sheet of paper, so that the insects upon them may be more easily seen, and have less chance of escape. Probably many Ants will be found clinging to the stones, but a quick eye will soon distinguish here and there amongst them strangers of some sort or other, which will probably turn out to be some of the beetles aforesaid. If it is desired to preserve the beetles, they may be gently removed and transferred to a bottle containing a few lumps of cyanide of potassium covered with pads of blotting paper; the poisonous vapour from this will soon kill them, and they may then be gummed on card for preservation and examination. As most of them are active in their movements, it will require a little dexterity to prevent their escape, and secure their safe transfer to the killing bottle. The fragments of stick at the top of the nest may be tapped or shaken over the cloth, or over a piece of white paper, when any insects that are in hiding will come tumbling out and may be secured. The stones and other traps may now be replaced, and the nests visited again at intervals during the spring or early summer, when no doubt other specimens will be obtained. It is best to visit the nests early in the day, before ten o'clock in the morning being, according to the late Mr. Janson, the best time to find the beetles. Of course, the method of procedure will be varied with the character of the nest; in the case of those Ants that do not throw up mounds of vegetable fragments, search must be made around the nest, and under any sheltering objects that may happen to lie about in the immediate neighbourhood. If the nest is under a stone, lifting this will often disclose some of the visitors, and again, the "runs" of the Ants may be profitably inspected.

The terms on which the beetles are associated with the Ants do not appear to be the same in all cases, and indeed in many instances it cannot be said to be satisfactorily determined what the terms are. Speaking generally, it is obvious that, to say the least, the presence of the beetles must in all cases be tolerated; for such is the energy and courage of Ants that they are not likely tamely to submit to the intrusion of interlopers which are decidedly distasteful; such would be at once attacked and killed, the jaws of the workers being quite capable of thus executing the capital sentence. Mere toleration and indifference, however, by no means represents the attitude of the Ants in all cases; in some instances there seems to be a certain amount of distrust and suspicion, but in others quite the reverse. Some are on terms of the closest intimacy with their hosts, by whom they are treated carefully and tenderly, and their presence is evidently valued. Speaking

at present only of the Brachelytra, and remembering that the general function of these insects in Nature is that of scavengers, one sees that it is not at all unlikely that such a function is discharged in the Ants' nests by at least some of the species found therein. The need of some arrangement analogous to sewage works, to dispose of the considerable amount of excrement and other refuse matters that must tend to accumulate in large communities of Ants, is obvious, and it may well be that a share at least of this work falls to the lot of the Ants' guests. Dr. Michael has recently shown that in the nests of certain Ants which he found in Corsica a kind of mite occurs, to which the Ants seem greatly attached; and a reason for this has been suggested by him as being found in the fact that the mites feed upon the bodies of dead Ants, and thus help the members of the community to a solution of the vexed question of the disposal of the dead, which cannot but be a matter of perplexity to all societies and great aggregations of living beings, increasing in difficulty in proportion to their size. In most cases the dead seem to be carried out of the nest, and the Rev. Farren White records a curious instance in which some little paper trays, which he had put upon one of the nests he kept for observation, were used as cemeteries, the Ants dropping the dead bodies of their companions into them one after the other. From the method in which the nest was in this case preserved for observation, viz., in a glass bell-jar, the bottom of which was wholly occupied by the nest, it would seem that this was the only method available by the Ants of putting the corpses into any spot where they could really be considered to be removed from the nest, and the Ants certainly deserve credit for the ingenuity of the device by which they overcame the difficulty presented by the glass walls of their prison.

No doubt in some instances the Ants and their guests are found together merely because they happen to prefer similar situations to live in, so that in such cases no particular significance can be attached to the association. Thus, if both delight to live under the bark of trees, or amongst the roots of grass, here is a bond of connection which will lead to their being found together unless either party objects; still, even in such cases, as the Ants, being always the more numerous of the two, could if they liked rid themselves of their companions, it is plain that the association is not distasteful to them. The mere accumulation of piles of vegetable fragments, such as those erected by the mound-builders, would tend to induce beetles to enter, as they often delight to lie concealed amongst vegetable rubbish, and it is certain that if any such mound were deserted by the Ants, it would very soon be tenanted by all sorts of different insects, as well as woodlice, centipedes, millipedes, &c. That such indefinite tenantry does not occur while the place is occupied by the Ants must therefore be attributed to their own efforts. Again, when fragments are brought in for addition to the mound, it is quite possible that they may sometimes contain upon their surface or in their interior either small insects or the eggs of such, so that we have here another possible means of the introduction of insects into the nests. On the whole, therefore, it would seem to be, not so much a matter of surprise that insects other than Ants are to be found in the nests of the mound-builders, but rather that their number is not even greater than it is. Of course, these remarks do not equally apply to those which do not throw up mounds; but then these do not, as a rule, yield so great an alien population.

We may now proceed to consider somewhat more in detail some of the most remarkable of these companions of Ants. Of the Brachelytra, one of the most curious is *Atemeles emarginatus* (Fig. 1). It is a reddish-brown insect scarcely more than a sixth of an inch in length, but broad out of proportion. It has a broad shield-like thorax, ending in thin leaf-like edges at the sides, and in sharp-pointed projections at the hinder angles. It has the habit of curling up the tip of its abdomen as it runs about, and this of course makes it look smaller than it really is. It can also roll itself up almost into a ball. It is so peculiarly shaped that it cannot easily be confounded with any other British insect. It is found in the nests of several species of Ants, especially the red stinging Ants (*Myrmica*), the blackish-brown *Formica fusca*, and the shining black *F. fuliginosa*. A good many of the beetles may often be obtained from one nest, though always the Ants far outnumber them. Wasmann records having found as many as one hundred and fifteen specimens in one nest of *Myrmica scabrinodis*. This is one of the insects that are very tenderly cared for by the Ants. It lives with them on terms of the closest intimacy, being often carried about by them from place to place. But more than that, the beetles are, at least to some extent, actually supported by the Ants, being fed by them from their own mouths, just as they would feed their young. If the beetle wants food, it approaches an Ant, and planting itself in front, with its tail cocked up, begins to stroke the Ant with its antennæ; the Ant soon responds and passes food into its mouth, continuing the operation perhaps for about half a minute, when it goes off about its business. Sometimes indeed the feeding takes longer, and some two or three minutes may be occupied in the process. It must not be imagined from this, however, that *Atemeles* has lost the power of feeding itself; this does not appear to be the case, although, according to Wasmann, the beetles flourish better when fed by the Ants. The same observer has mentioned that the Ants lick with apparent gratification certain tufts of yellow hairs which are found on the beetle's body, as though they yielded some secretion which was pleasant to the taste. He also mentions that the beetles have the power of exhaling an agreeable aromatic odour from a gland in the abdomen, similar to, but stronger than the scent of *Myrmica*, which arises from the head. The beetle enjoys a good deal of freedom of movement, notwithstanding the care of the Ants, and during the summer months it is not to be found in the nests. But if the beetles at other times manifest a tendency to wander too far, they are picked up by their guardians and carried back again. We have here, then, the case of a beetle which is closely associated with the life of the Ants, and is carefully tended, guarded, and fed by them, and yet which has so far retained its faculties and powers almost if not entirely unimpaired, and does not seem to have become degraded by its dependence. That such, however, is not always the case will be evident from other instances, which want of space compels us to defer till next month.

*(To be continued.)*

## HOT SPRINGS.

By Prof. J. LOGAN LOBLEY, F.G.S.

THERMAL springs vary so greatly in temperature that to a large number the word "hot" is not applicable, and yet these cannot be excluded from consideration in connection with the subject of Hot Springs, since they are essentially of the same class of phenomena.

All springs of water the temperature of which is higher than that of the rocks from which they issue may be

regarded as thermal springs, since they have derived their exceptional heat from subterranean, and therefore extra-meteoric, sources.

The thermal springs of non-volcanic countries, although frequently but slightly heated, are in some respects the most noteworthy, for the cause of their heat, not being obvious, an attractive and interesting enquiry is suggested. Such are the thermal springs of England and Germany.

In England five have long been known. The most famous and the hottest is that of Bath, which has a temperature of 120° Fahrenheit, and then follow those of Buxton at 83°, Clifton at 76°, Matlock at 68°, and Ashby-de-la-Zouch at 62°. Very similar in many respects to the English springs are those of Germany, which have a world-wide fame, and are the resort of an annually-increasing number of both health and pleasure seekers. The range of temperature of these waters is considerably greater than that of our home springs, the Sprudel Quelle of Carlsbad having a temperature of 167° Fahrenheit. With the exception of the springs of Gastein, they are all in three districts—Nassau, the Schwarzwald or Black Forest (parts of Baden and Wurtemberg), and Bohemia. Their temperatures are as follows :—

| | |
|---|---|
| Carlsbad, Bohemia (the Sprudel Quelle) . | 167° F. |
| Wiesbaden, Nassau (the Kochbrunnen) . | 158° ,, |
| Baden, Baden (the Ursprung) . . | 153° ,, |
| Toeplitz, Bohemia (the Stadtbad) . . | 122° ,, |
| Gastein, Austria (the Spital Quelle) . | 118° ,, |
| Ems, Nassau (the Kesselbrunnen) . . | 118° ,, |
| Wildbad, Wurtemberg (the Furstenbad) . | 98° ,, |
| Schlangenbad, Nassau (the Altbad) . | 86° ,, |
| Liebenzell, Wurtemberg . . . | 76° ,, |
| Soden, Nassau . . . . . | 75° ,, |
| Cannstadt, Wurtemberg . . . . | 66° ,, |

Hotter, however, than any of the above-named waters is that of Abano, in North Italy, about five miles from Padua, which has a temperature of 187° Fahrenheit. It is true this place is at a seat of former volcanic activity, the Euganian Hills, but the period of that activity was as far back as Eocene times.

One of the most remarkable examples of Hot Springs in non-volcanic regions is that of Hammam-Meskhoutim, near Constantine, in Algeria, where the water, with a temperature of 203°, deposits calcareous travertine, and so forms piles of basins rising to about 30 feet. Another great deposit of travertine from such Hot Springs is at Hierapolis, in Asia Minor, where it forms white terraces on the side of the hill, on which in ancient times the water, at about 100° Fahrenheit, issued.

All these thermal springs, and many others in various parts of the world, agree in issuing from the rocks of regions of a markedly non-volcanic character, as those of England, or of areas where volcanic activity is apparently quite extinct. They all, therefore, require some hypothesis to account for their high temperature other than proximity to volcanic action.

The theory founded on the ascertained increase of heat with descent from the surface would put the source of the Bath water at about 4000 feet depth. A much less depth would be required by ascending hot fumes or gases meeting with water, and so heating and impregnating it and forcing it to the surface. The "physio-chemical hypothesis" that accounts for the production of volcanic heat at moderate depths by subterranean chemical action, when the conditions are favourable, appears to meet the case of the Bath waters, and that of other thermal springs in non-volcanic regions.*

* Reports of the British Association, Bath Meeting, 1888, p. 670.

One feature they have in common with all Hot Springs, wherever they may be found and of whatever temperature they may be, and this is that they are all more or less "Mineral Springs," and it is to this fact, together with their high temperature, that they owe their medicinal or curative reputation. Water is at ordinary temperatures a solvent of many substances, but at high temperatures of a greater number, and, too, of a greater quantity of those soluble in it when cold; and boiling water is a solvent to some extent of that usually most refractory substance, silica. Hence it is that boiling springs generally deposit from their cooling overflow water the solid silicious material, silicious sinter. It has been estimated that the matter held in solution by the Bath water, which has been derived from the rocks through which it has passed, would, if solidified, form annually a column having a base of nine square feet and a height of 140 feet. This matter consists chiefly of the sulphates of lime and soda and the chlorides of sodium and magnesium. A spring at Clermont, in France, has deposited a great mass of calcareous rock, forming a natural bridge of travertine, and other examples have been previously mentioned.

The thermal springs of volcanic regions which, from the evident cause of their heat, may be called volcanic thermal springs, are very conspicuously different in character, some being tranquil flows of heated water, some being in a state of ebullition more or less active, and others, the Geysers, being characterized by periodic ejections or eruptions of boiling water followed by violent explosions. There are, too, many thermal springs where there is at present no volcanic action, but yet these areas are so volcanic in character, and have been the seat of volcanic activity so late as post-Pliocene times, that the heating of the waters issuing from their rocks can only be ascribed to lingering volcanic fires.

Of those regions the old province of Auvergne, in France, is the most important in Europe. It has many thermal springs, of which those at Vichy, Vic en Carladez, Mont Dore les Bains, La Bourboule, and St. Nectaire are best known. And in America Hot Springs are conspicuous in such areas, in Utah, near Salt Lake City, where is Hot Springs Lake, and in Colorado, where are the important Pagazo Springs, and especially so in Wyoming.

The oldest known and longest used Hot Springs are those of the volcanic region of Southern Italy, where, near Naples, these *thermæ*, so greatly used by the patricians of old Rome, still give forth waters at the Baths of Nero, near the Lucrine Lake, of a temperature of 182° Fahrenheit, and at Pisciarelli, near the not yet quite extinct Solfatara, of 180° Fahrenheit, sufficiently hot, Dr. Daubeny found, to boil an egg in a few minutes; and across the blue waters of the Bay of Naples, on the volcanic island of Ischia, under the shadow of the slumbering volcano Epomeo, there are the now much used hot baths of Gurgitello. Some of the thermal springs of the remarkable volcanic district of the Phlegræan Fields are, however, of but moderate temperatures. At Bagnoli, near Pozzuoli, are two springs of 104° F., and the tepid waters of Baiæ made that place great and rich in ancient Roman times.

But it is that northern, indeed Arctic land, Iceland, of which most of us think when Hot Springs are named, for of these phenomena the geysers of Iceland received until recently the most prominent notice. There are other Hot Springs in Iceland, but geysers, or intermittent eruptive Hot Springs, are very numerous, both in the Hecla district and in other parts of the island.

The group best known consists of about a hundred, but so near together that they are all within an area of about two square miles. This place is about thirty miles from the active volcano Hecla, in the south-western part of Iceland. Two of the geysers—which are so named from the Icelandic word *geysa*, to rage — are conspicuously greater and more important than the others, and the larger of the two, called Great Geyser, has been carefully observed and described, first by Mackenzie, and afterwards by Bunsen, Descloiseaux, and others.

This intermittent natural fountain of boiling water has been found to have a shaft or tube descending to about 78 feet below the surface, with a diameter varying from 6 to 8 feet, which at the top expands into a funnel-shaped mouth or basin, 56 feet by 46 feet, that is really the crater of a mound sloping on all sides, from its margin to the level of the adjoining land. With intervals of about six hours between, a column of hot or boiling water is ejected high into the air, 100 to 200 feet. After this, which continues for five or six minutes, an explosion of steam occurs, the tube is emptied, and there is no more ejection of hot water for another period of six hours. During this time the tube gradually refills, when there is another ejection followed by a violent explosion of steam as before. Thus, throughout the year, amid the ice and snows of Iceland, this extraordinary periodical ejection of boiling water and steam goes on. The throat, the crater, and all around this aqueous volcano is coated with a deposit of silicious sinter, and it is an accumulation of this hard white material that has formed the mound and the sides of the basin from the centre of which the tube descends.

Although the great increase in recent years of our knowledge of the physical features of the earth's surface has made us acquainted with many other and greater eruptive boiling springs, yet the geysers of Iceland retain their place as types, and the hypotheses to explain geyser action are founded on the phenomena they present. Of these one of the first was that of Sir J. Herschel, who supposed a rock cavity holding water with a conduit from it to the surface passing through a stratum of very hot rock which would so greatly heat the water in passing as to cause the eruptive action. It was Bunsen, however, who was the author of the now generally accepted hypothesis — that the water as it collects from the surrounding rocks, in the lower part of the shaft, is heated by a hot zone to much over boiling point, as it was actually found by Bunsen to be 260° Fahrenheit within the tube, but that the pressure of the column of water above prevented the formation of steam. This goes on until the force generated overcomes the pressure, when the column of water above is ejected, and the lower water being relieved of the restraining pressure is suddenly converted into steam, and so produces the final explosion and emptying of the shaft. This action has been imitated by an arrangement devised by Professor Tyndall, who also illustrated the bringing about of premature eruptions of the geyser called the Strokkr by obstructing its tube with clods of earth.

A much grander exhibition of thermo-hydraulic action was displayed on the opposite side of the globe, when Von Hochstetter, in 1859, explored the volcanic regions of the North Island of New Zealand. From one point could be seen on both sides of the valley of the River Waikato 76 clouds of steam arising from hot cascades, falling into the river from white basins, some with rising and falling fountains, some pausing, some playing simultaneously, and so forming a wonderful system of grand natural water-works. The steaming cascades fell over white, red, and yellow terraces, while periodical eruptions occurred at points between them.

Still greater wonders were found to the north-west of the valley of the Waikato, where was the now famous lake of Roto Mahana, a lake of warm water, amidst boiling springs that were continually pouring into it immense volumes of hot water over marble-like terraces, on the hill slopes around. On a small island in the lake, potatoes and meat could be cooked by the steam given out whenever a little hole was dug in the ground. Te Tarata, "the Tattooed Rock," rose on the east side of the lake to a height of 80 feet in snow-white terraces, and on its summit was an immense basin filled to the brim with water boiling, but clear and of a brilliant blue tint. The white terraces over which the water fell in cascades to the lake, formed by the deposition of silica by the cooling water, had on each level basins, with projecting semi-circular margins, and holding bright blue water, from which stalactites of pure silica depended, and added a light and fairy-like beauty to this marvellous piece of natural architecture. Other boiling springs, with descending terraces, were on this side of the lake, and they were confronted on the west side by Otukapuarangi displaying its pink terraces, which, with the blue waters surrounded by red, white, and yellow walls of rock, added additional colour to the wonderful scene.

It has been necessary to write of these marvels of the Roto Mahana lake in the past tense, as they are things of the past, for in June, 1886, a great volcanic eruption completely destroyed the terraces, the springs, and even the lake itself. Had, therefore, this part of New Zealand not then been explored, mankind would not have known of these magnificently beautiful wonders of Nature in the Britain of the Southern Seas.

To find a still more extensive display of Hot Springs we must return to the northern hemisphere, and visit that remarkable area in Wyoming, the Yellowstone National Park, in which are congregated so many natural wonders, and which has recently been described in these pages.

The thermo-aquatic phenomena here seen are on a much grander scale than anywhere else, but it is impossible now to do more than very briefly state the general character of these marvels. In addition to other parts of this region, in which there are numerous Hot Springs, both tranquil and eruptive, there is an area occupied by an unexampled development of the one class, and a second in which are concentrated extraordinary groups or collections of the other class. The former of these areas is that of the "Mammoth White Mountain Hot Springs." These in their character and surroundings resemble those of the destroyed White and Pink Terraces of New Zealand, but instead of silicious they deposit calcareous matter, and they are on a larger scale. The terraces are as brilliantly white, the water is as clear and blue, and the other colours are as varied and vivid as were those around the Roto Mahana lake. Stalactites, coral-like forms, and exquisite bead-work ornament the terraced basins and the platforms that cover the entire face of the mountain, rising from the banks of Gardiner's River at 5845 feet above the level of the sea to 6522 feet. An analysis of the travertine of the terraces formed by these springs, given by Dr. Hayden, is as follows:—

| | | |
|---|---|---|
| Water and volatile matters ... | 32·10 | per cent. |
| Lime ... ... ... ... | 57·70 | ,, |
| Silica ... ... ... ... | 3·32 | ,, |
| Ferric Oxide ... ... ... | 3·62 | ,, |
| Alumina ... ... ... | 3·31 | ,, |
| Soda and magnesia ... ... | traces | |
| | 105·05 | ,, |

The other most noteworthy Hot Springs area of the Yellowstone Park is called the "Geyser Basins of the Fire Hole River," consisting of the Lower Basin and the Upper Basin, altogether about 75 square miles.

The Lower Basin contains thousands of springs of various temperatures, including some gigantic geysers of which the "Fountain" and the "Architectural" geysers are the best known. There are also "Mud Puffs," or centres of boiling mud. The Upper Basin has geysers of still greater importance and becoming famous under the names of "Old Faithful," "The Giant," "The Giantess," "The Grand," "The Castle," "The Beehive," &c. All these, like the Geysers of Iceland, deposit silicious sinter or geyserite, of which Dr. Hayden's analysis is:—

| | |
|---|---|
| Water ... ... ... | 13·42 per cent. |
| Silica .. ... ... ... | 76·80 ,, |
| Alumina ... ... | 9·46 ,, |
| Lime ... ... ... ... | 1·80 ,, |
| Iron, magnesia, and soda .. | traces |
| | 101·06 ,, |

Although the Yellowstone Valley has long ago ceased to be the scene of volcanic activity, great subterranean heat still lingers beneath its mountains, cañons and lakes, and now presents to the admiration of mankind phenomena as beautiful as they are wonderful.

## THE FACE OF THE SKY FOR MAY.

By Herbert Sadler, F.R.A.S.

SMALL groups of spots and faculæ continue to appear on the solar surface. The following are conveniently observable times of the minima of some Algol-type variables (*cf.* "Face of the Sky" for April). S Cancri.—May 11th, 9h. 32m. P.M.; May 30th, 8h. 48m. P.M. δ Libræ.—May 4th, 8h. 28m. P.M.; May 11th, 8h. 3m. P.M. U Coronæ.—May 13th, 10h. 49m. P.M.; May 20th, 8h. 31m. P.M.

Mercury is technically a morning star throughout May, but is practically invisible, as on the first day of the month he only rises 24 minutes before the Sun, and on the last day of May he rises three-quarters of an hour before the Sun. Under these circumstances an ephemeris of the planet would be useless. He is at his greatest western elongation (25½°) on the 17th.

Venus is a superb object in the evening sky, and is visible to the naked eye at noonday when her position is accurately known. She sets on the 1st at 11h. 49m. P.M., with a northern declination of 26° 49′, and an apparent diameter of 23″, just one half of the disc being illuminated. On the 15th she sets at 11h. 50m. P.M., with a northern declination of 26° 30′, and an apparent diameter of 28″, $\frac{41}{100}$ths of the disc being illuminated. On the 30th she sets at 11h. 21m. P.M., with a northern declination of 24° 35′, and an apparent diameter of 35½″, just three-tenths of the disc being illuminated. During the month she pursues a direct path through Gemini, without approaching any conspicuous star very closely. At about 10h. 20m. P.M. on the 3rd a 9th magnitude star will be just north of the planet, and at 10h. 30m. P.M. on the 13th a 9½ magnitude star will be very closely north of Venus, while at 10h. 10m. P.M. on the 21st a 9¼ magnitude star will be immediately south of the planet.

Mars does not rise till after midnight on the last day of the month, and Jupiter is, for the observer's purposes, invisible.

Saturn is still well situated for observation. He rises on the 1st at 2h. 34m. P.M., with a northern declination of 4° 43′, and an apparent equatorial diameter of 18·5″ (the major axis of the ring system being 42·8″ in diameter, and the minor 0·4″). On the 31st he rises at 0h. 32m. P.M., with a northern declination of 4° 48′, and an apparent equatorial diameter of 17¾″ (the major axis of the ring system being 40·8″ in diameter, and the minor 0·3″). The ring system is therefore invisible in small telescopes. The following phenomena of the satellites may be observed (the times are given to the nearest quarter of an hour). May 1st, 1¼h. A.M., Tethys, eclipse reappearance; May 2nd, 10½h. P.M., Tethys, eclipse reappearance; May 4th, 8 P.M., Tethys, eclipse reappearance; May 9th, 8¾h. P.M., Dione, eclipse reappearance; May 18th, 1h. A.M., Tethys, eclipse reappearance; 1¾h. A.M., Dione, eclipse reappearance; May 19th, 10¾h. P.M., Tethys, eclipse reappearance. Iapetus is at his greatest western elongation on the morning of May 27th. On the 9th at about 11h. P.M. a 9½ magnitude star will be about ¾′ south of the planet. During May Saturn describes a very short retrograde path through part of Virgo, without approaching any naked-eye star.

Uranus is well situated for observation, rising on the 1st at 6h. 25m. P.M., with a southern declination of 12° 17′, and an apparent diameter of 3·8″. On the 31st he rises at 4h. 20m. P.M., with a southern declination of 11° 54′. During the month he describes a retrograde path to the N.W. of λ Virginis. A map of the path of Uranus is given in the *English Mechanic* for February 12th. Neptune is in conjunction with the Sun on the 29th.

There are no very well marked showers of shooting stars in May.

The Moon enters her first quarter at 7h. 12m. P.M. on the 3rd; is full at 10h. 59m. P.M. on the 11th; enters her last quarter at 2h. 53m. P.M. on the 19th; and is new at 5h. 49m. A.M. on the 26th. She is in apogee at 5·3h. A.M. on the 9th (distance from the earth 252,310 miles); and in perigee at 4·6h. P.M. on the 24th (distance from the earth 224,215 miles). Her greatest western librations occur at 0h. 54m. P.M. on the 2nd, and at 5h. 30m. P.M. on the 30th; and her greatest eastern at 5h. 35m. A.M. on the 18th. There will be an eclipse of the Moon on May 11th, the first contact with the penumbra taking place at 7h. 55·9m. P.M.; the first contact with the shadow (at an angle of 82° from the most northern portion of the Moon's limb towards the east, for *direct* image); the last contact with the shadow at 0h. 36·6m. A.M. on the 12th (at an angle of 41° from the most northern portion of the Moon's limb towards the west, for *direct* image); and the last contact with the penumbra at 1h. 50·9m. A.M. on the 12th. The middle of the eclipse occurs at 10h. 53·4m. P.M. on the 11th, $\frac{953}{1000}$ths of the lunar disc being obscured.

## Chess Column.

By C. D. Locock, B.A.Oxon.

All communications for this column should be addressed to the "Chess Editor, *Knowledge Office*," and posted before the 10th of each month.

*Solution of Problem in April number.*—1. Q to B7, and mates next move.

Correct Solutions received from H. S. Brandreth, C. T. Blanshard, A. H. C. Hamilton, "T. Wells."

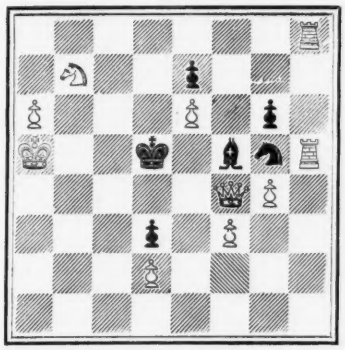
"*T. Wells.*"—1. BR6 will not solve the March problem. The move fails against one defence only, viz.: 1. . . . K to B5.

*C. T. Blanshard.*—Thanks for the problem; it is printed below.

## PROBLEM.

By C. T. BLANSHARD.

BLACK.



WHITE.

White to play, and mate in two moves.

## CHESS INTELLIGENCE.

The result of the Amateur Championship Tournament of the British Chess Association was as follows:—

| | |
|---|---|
| 1. E. Jones-Bateman ... ... ... | 9½ |
| 2. H. W. Trenchard ... ... ... | 7 |
| 3. E. O. Jones... ... ... ... | 6½ |

Mr. Jones took the third prize after a tie with Mr. Herbert Jacobs, who is fourth. The other competitors were Dr. Smith, Messrs. Ward-Higgs and Gibbons, all of whom met with some success in the recent City of London Club Tournament.

It will be seen that Mr. Jones-Bateman won with a good deal to spare, Mr. Trenchard being rather a bad second. This is the first occasion on which the winner has not been a member of the British Chess Club. Mr. Jones-Bateman is the present holder of the Löwenthal Cup, which carries with it the championship of the St. George's Chess Club.

## THE CHAMPIONSHIP TOURNAMENT.

At the conclusion of the National Masters' Tournament Mr. G. Newnes, M.P., the president of the British Chess Club, offered prizes amounting to £50 for a two-game tournament between the five leading London players. The masters selected were Messrs. Bird, Blackburne, Gunsberg, Lasker, and Mason. As in the previous tournament, Mr. Lasker again came out first, and, but for his willingness to accept draws with Mr. Mason, could no doubt have increased the distance between himself and Mr. Blackburne, whom he defeated by very fine play in both games. Mr. Blackburne, moreover, was extremely fortunate in winning his second game with Mr. Bird, a game which he played only to draw by perpetual check. He was also a little lucky in winning two games from Mr. Mason, both of which looked like certain draws. On the other hand, his first game with Mr. Bird was a fine specimen of counter-attack. Mr. Mason played as well as he usually does, while the other two competitors were apparently out of form. The following was the score:—

| | |
|---|---|
| 1. E. Lasker ... ... ... ... | 6½ |
| 2. J. H. Blackburne ... ... | 6 |
| 3. James Mason ... ... | 4 |
| 4. I. Gunsberg... ... | 2½ |
| 5. H. E. Bird ... ... ... ... | 1 |

The prizes were divided on the Sonneborn-Berger system, *i.e.*, according to the *value* of the games won by each player, estimated by the scores of the players from whom they were won. On this system Mr. Lasker, who did not lose a single game, came out easily first, and his performance confirms the estimate of his capacity given in this column last month.

## THE UNIVERSITIES WEEK.

The boat-race week was, as usual, crowded with matches in which the Oxford and Cambridge teams were engaged. The first contest, between past members of the two clubs, was decided on the Tuesday at the St. George's Chess Club. The old Oxonians, who missed the services of Messrs. W. M. Gattie and G. E. Wainwright, gained a rather unexpected victory over their more mathematical opponents. The score was:—

| OXFORD. | | CAMBRIDGE. | |
|---|---|---|---|
| 1. C. D. Locock (University Col.) (unfinished) ... ... | — | *v.* Rev. A. B. Skipworth (St. Catherine's) (unfinished) ... ... | — |
| 2. E. M. Jackson (New College) ... ... | ½ | *v.* W. H. Gunston (St. John's) ... ... ... | ½ |
| 3. Rev. L. W. Lewis (Lincoln) ... ... | *½ | *v.* J. N. Keynes (Pembroke) ... ... ... | *½ |
| 4. H. F. Lowe (Balliol) | 1 | *v.* W. Deighton (St. John's) ... ... ... | 0 |
| 5. R. W. Barnett (Wadham) ... ... ... | 1 | *v.* Rev. J. F. Sugden (Trinity Hall) ... | 0 |
| 6. E. Anthony (Ch. Ch.) | 0 | *v.* F. P. Carr (St. Cath.) | 1 |
| 7. Rev. W. Cooper (Wadham) . . ... ... | 1 | *v.* E. L. Kearney (St. Catherine's) ... ... | 0 |
| 8. Rev. W. M. Le Patourel (Balliol)... | ½ | *v.* W. R. Fisher (St. John's) ... ... ... | ½ |
| | 4½ | | 2½ |

On the same evening a combined team of present members of the two Universities, assisted by Mr. E. M. Jackson, suffered a defeat at the hands of a City of London team by 13—7.

On the Thursday following, the Oxford and Cambridge match took place at the British Chess Club. Cambridge were the favourites, and fully justified the fact, not allowing their opponents to win a single game. In the absence of clocks the rate of play was much slower than usual, and only one game was played at each board. The following was the score:—

| OXFORD. | | CAMBRIDGE. | |
|---|---|---|---|
| 1. D. Madgavkar (Balliol) ... ... ... | 0 | *v.* H. E. Atkins (Peterhouse) ... ... ... | 1 |
| 2. R. Lynam (non. col.) | ½ | *v.* H. S. Bullock (Corpus) | ½ |
| 3. F. E. Jelly (Magdalen) | ½ | *v.* F. G. Scovell (Queen's) | ½ |
| 4. A. B. Hinds (Ch. Ch.) | ½ | *v.* E. Young (Corpus) ... | ½ |
| 5. G. A. Heginbotham (Pembroke) ... ... | 0 | *v.* W. C. Sandford (Queen's) ... ... | 1 |
| 6. P. L. Osborn (Magdalen) ... ... ... | 0 | *v.* E. B. James (Caius) | 1 |
| 7. P. Sergeant (Trinity) | 0 | *v.* J. H. Percival (Trin. Hall) ... ... ... | 1 |
| Total ... ... | 1½ | Total ... ... | 5½ |

* The game on No. 3 board was adjudicated by the umpire (Mr. James Innes Minchin) as drawn.

The usual banquet and smoking concert followed in the evening at the British Chess Club, the Lord Mayor being in the chair. On the following afternoon the Oxford Club defeated a rather weak team of the St. George's Chess Club by 5½ to 2½. In the evening Cambridge, assisted by several old members, gained a victory over the British Chess Club by 7½ to 4½, the latter club playing a rather weak team, and losing on the four last boards.

Finally, on the evening of the boat race, the Sussex Chess Association, by no means playing their full strength, defeated a combination of present members of the two Universities by 10—6.

## COUNTIES' CHESS ASSOCIATION PROBLEM TOURNAMENT.

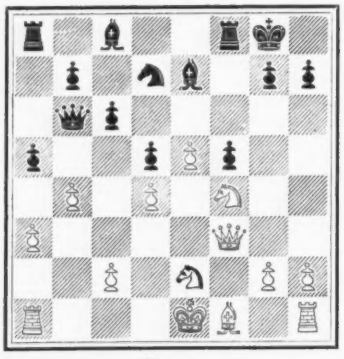
First prize, £2 2s.; second prize, £1 1s. The time for sending in is extended to 30th June, 1892. For full particulars write to Rev. A. B. Skipworth, Tetford Rectory, Horncastle.

The following fine game was played in the late tournament :—

[VIENNA OPENING.]

| WHITE (J. H. Blackburne). | BLACK (E. Lasker). |
|---|---|
| 1. P to K4 | 1. P to K4 |
| 2. Kt to QB3 | 2. Kt to KB3 |
| 3. P to B4 | 3. P to Q4 |
| 4. P takes KP | 4. Kt takes P |
| 5. Q to B3 | 5. P to KB4 (*a*) |
| 6. Kt to R3 (*b*) | 6. P to B3 (*c*) |
| 7. Kt to K2 (*d*) | 7. B to K2 |
| 8. P to Q3 | 8. Kt to B4 |
| 9. P to R3 (*e*) | 9. Castles |
| 10. B to K3 | 10. QKt to Q2 |
| 11. B takes Kt | 11. Kt takes B |
| 12. Kt (R3) to B4 | 12. Q to Kt3 (*f*) |
| 13. P to QKt4 (*g*) | 13. Kt to Q2 |
| 14. P to Q4 | 14. P to QR4 ! |

BLACK.



WHITE.

| | |
|---|---|
| 15. R to QKtsq | 15. P takes P |
| 16. P takes P | 16. B takes Pch |
| 17. P to B3 | 17. B takes Pch |
| 18. Kt takes B | 18. Q takes P |
| 19. Kt to K2 | 19. Q takes P |
| 20. Q to B4 | 20. Q to B3 |
| 21. Kt to Q4 | 21. Kt to B4 ! |
| 22. Q to Q2 (*h*) | 22. Kt to K5 |
| 23. Kt takes Kt | 23. BP takes Kt |
| 24. Q to K3 | 24. R to R5 |
| 25. Kt to B2 (*i*) | 25. R to R7 |
| 26. R to Bsq | 26. B to Kt5 |
| 27. B to K2 | 27. B takes B |
| 28. K takes B | 28. Q to Kt7 |
| 29. K to Qsq | 29. Q to Kt4 |
| 30. R to Ksq | 30. R to Kt7 (*j*) |
| 31. Q to K2 (*k*) | 31. Q to Q6ch |
| 32. Q takes Q | 32. P takes Q |
| Resigns. | |

NOTES.

(*a*) 5. . . QKt to B3 is another good defence. White's best reply is 6. B to Kt5 : for if 6. Kt × Kt, Kt to Q5 ; 7. Q to Q3, P × Kt ; and he dare not take the Pawn on account of 8. . . B to KB4.

(*b*) If 6. P to Q3, Kt × Kt; 7. P × Kt, P to Q5 ! with a good game. Or if 6. P × P *en passant*, Kt × P ; 7. P to Q4, B to QKt5, followed by Castles.

The best move according to Bardeleben is 6. KKt to K2, P to B3 ; 7. Kt to B4. Mr. Blackburne's move is not so good :—

(*c*) For here Black should surely play 6. . . QKt to B3, a move which, if the White Knight had played to K2, would of course be met by P to Q4.

(*d*) 7. Kt to B4 would now give White the superior game. The opening is rather indifferently played on both sides.

(*e*) Not quite unintelligible, for if 9. B to K3 at once, Q to Kt3 ! and White can neither Castle comfortably nor play R to QKtsq without losing a Pawn.

(*f*) Best probably ; though P to KKt4 is also tempting, White's best reply being P to Q4.

(*g*) This weakens his game terribly ; but R to QKtsq is also disadvantageous. After this Mr. Lasker does not give his opponent a chance.

(*h*) 22. B to K2 would be met by Kt to K3 !, winning a piece.

(*i*) Kt to Kt3 may be a shade better, but the game is lost anyhow.

(*j*) In order that the Knight may not be able to attack the Rook after the contemplated exchange of Queens.

(*k*) This loses right off, but there is not much to do. On his next move, if 32. Q to Q2, R to B7 wins a piece by force.

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*TERMS OF SUBSCRIPTION.*

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